THE

# Mine Foreman's

# POCKET BOOK,

EDITED BY


## THOMAS J. FOSTER,

*Editor of the Mining Herald.*



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1883.

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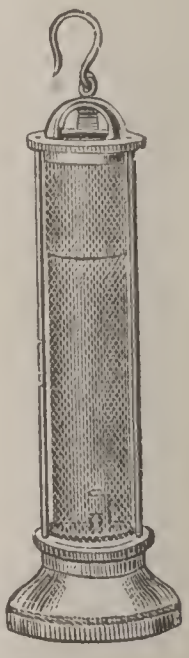

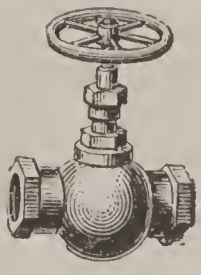

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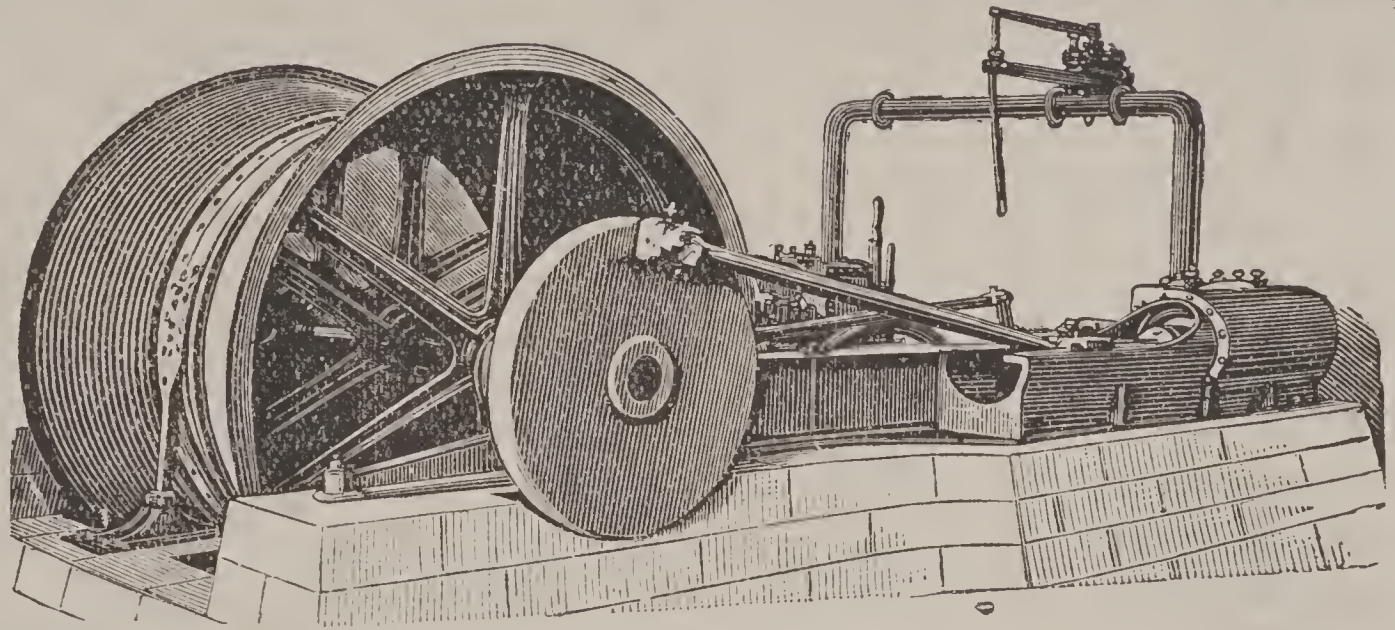

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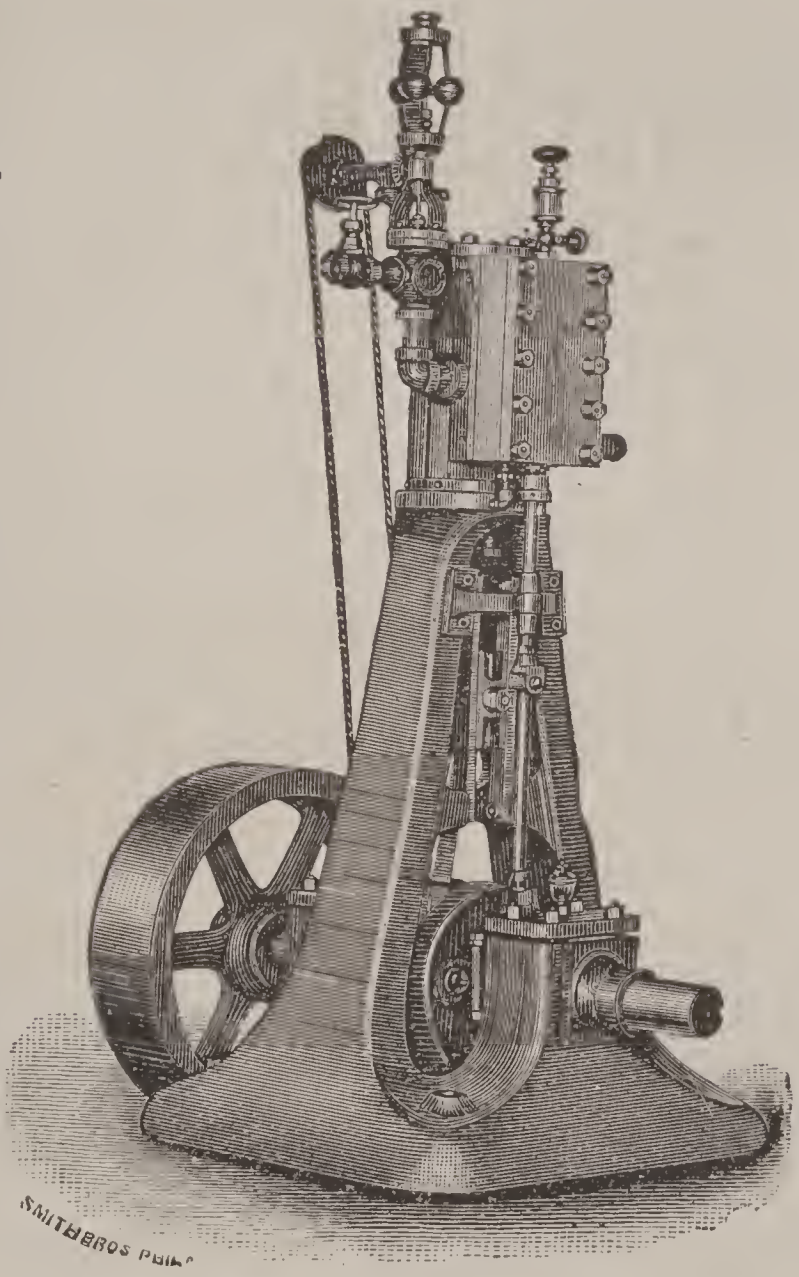

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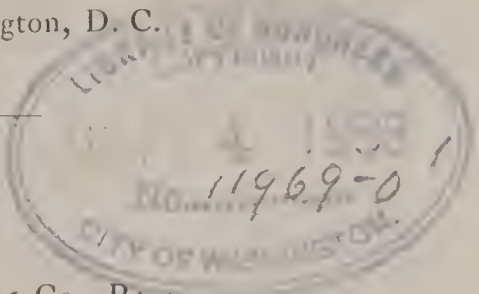


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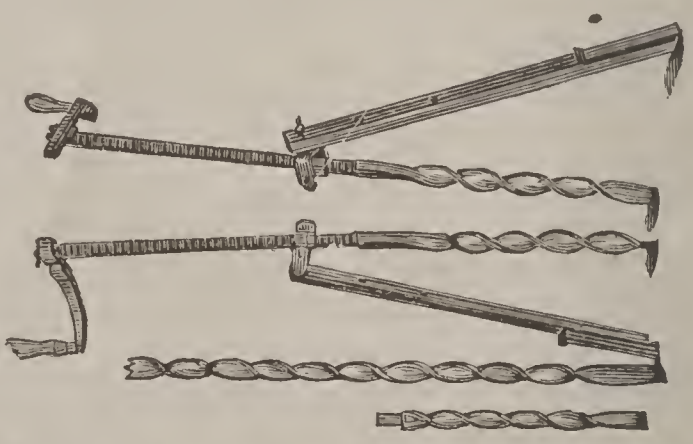

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# EDITOR'S ANNOUNCEMENT.

The demand for the MINE FOREMAN'S POCKET BOOK has far exceeded our expectations, and the several large editions issued during the past few years were so rapidly exhausted that we were unable to issue the third edition before the second was fairly disposed of. This demonstrates that American miners thoroughly appreciate technical education and realize its importance. This edition, it will be seen, has been greatly enlarged, improvements having been added to the subjects of Ventilation, Engines and Boilers, Ropes, Drums, Mathematics, etc., with a department on Machinery, etc. We have inserted the table of Natural Sines instead of that on Incline Measures, and largely explained its use, which we think our patrons will find more serviceable without the calculations requiring its use having lost any of their simplicity. We are indebted for material to the Colliery Manager's Pocket Book, Almanac and Diary and the Colliery Manager's Calculator of Mr. W. Fairley, M. E., of England, Molesworth's Pocket Book, Brigg's Useful Information and other authorities, most of whom have received credit in the body of the book.

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# AREA OF THE COAL FIELDS OF THE UNITED STATES, AND PRODUCTION FOR 1880.

| | States and Territories. | | Area square miles. | Tons produced in 1882. |
|---|---|---|---|---|
| 1 | Penn'a | Anthracite | 472 | 30,537,997 |
| | | Bituminous | 12,302 | 25,663,283 |
| 2 | Ohio, | do | 10,000 | 9,450,000 |
| 3 | Illinois, | do | 36,800 | 9,115,653 |
| 4 | Iowa, | do | 18,000 | 3,127,700 |
| 8 | Maryland, | do | 550 | 1,591,918 |
| 7 | W.Virginia, | do | 16,000 | 1,900,000 |
| 5 | Indiana, | do | 6,450 | 2,000,000 |
| 6 | Missouri, | do | 26,887 | 2,000,000 |
| 10 | Kentucky, | do | 12,871 | 1,275,000 |
| 11 | Tennessee, | do | 5,100 | 852,000 |
| 14 | California, | do | ..... | 700,000 |
| 9 | Colorado, | do | ..... | 1,588,000 |
| 13 | Kansas, | do | 22,256 | 770,000 |
| 16 | Oregon, | do | ..... | 300,000 |
| 12 | Alabama, | do | 5,330 | 800,000 |
| 18 | Washington, | do | ..... | 263,256 |
| 15 | Wyoming, | do | ..... | 624,700 |
| 22 | Virginia, | do | 185 | 100,000 |
| 20 | Michigan, | do | 6,700 | 140,000 |
| 21 | Nebraska, | do | 3,000 | 100,000 |
| 17 | Utah, | do | ..... | 275,000 |
| 23 | R. Island, | do | 500 | 15,000 |
| 24 | Arkansas, | do | 12,000 | . . . |
| 25 | Texas, | do | 20,000 | . . . |
| 19 | Georgia, | do | ..... | 150,000 |
| 26 | Arizona, | do | 30,000 | . . . |
| | Total | | . . . | 93,338,507 |

## COAL AREAS AND OUT-PUT OF THE GLOBE

## (ESTIMATED.)

| Countries. | Area Square Miles. | Tons—1870. | Tons—1880. |
|---|---|---|---|
| Great Britain . . . | 11,900 | 110,431,192 | 146,818,622 |
| United States . . . | 192,000 | 32,863,690 | 71,067,576 |
| Germany. . . . . | 1,770 | 34,003,004 | 52,047,832 |
| France. . . . . | 2,086 | 13,179,708 | 19,412,112 |
| Belgium . . . | 510 | 13,697,118 | 16,887,047 |
| Austria . . . . . | 1,800 | 8,355,944 | 16,500,000 |
| Russia . . . . . | 30,000 | 829,745 | 3,218,661 |
| Spain . . . . . | 3,501 | 661,927 | 800,000 |
| Nova Scotia . . . . | 18,000 | 625,769 | 1,032,710 |
| Australia. . . . . | 24,840 | 868,564 | 1,571,736 |
| India . . . . . | 2,004 | 500,000 | 4,000,000 |
| Japan . . . . . | 5,000 | . . | 850,000 |
| Vancouver's Island.. | 390 | 29,863 | 282,128 |
| China, Chili, etc . . | . . . | 4,000,000 | 4,300,000 |
| Total. . . . . | 293,801 | 214,046,524 | 338,788,424 |

## ANTHRACITE COAL TONNAGE BY DECADES.

| Year. | Schuylkill. | Lehigh. | Wyoming. | Total. |
|---|---|---|---|---|
| 1820. . . | . . | 365 | . . . | . . . |
| 1830. . . | 89,984 | 41,750 | 43,000 | 174,734 |
| 1840. . . | 490,596 | 225,313 | 148,470 | 864,379 |
| 1850. . . | 1,840,620 | 690,456 | 827,823 | 3,358,899 |
| 1860. . . | 3,749,632 | 1,821,674 | 2,941,817 | 8,513,123 |
| 1870. . . | 4,968,157 | 3,239,374 | 7,974,660 | 1,6182,191 |
| 1880. . . | 7,554,742 | 4,463,221 | 11,419,279 | 23,437,242 |

## ANTHRACITE COAL TONNAGE OF LAST DECADE BY REGIONS.

| Year. | Schuylkill. | Lehigh. | Wyoming. | Total. |
|---|---|---|---|---|
| 1871... | 6,552,772 | 2,235,707 | 6,911,242 | 15,699,721 |
| 1872 .. | 6,694,890 | 3,873,339 | 9,101,549 | 19,669,778 |
| 1873... | 7,212,601 | 3,705,596 | 10,309,755 | 21,227,952 |
| 1874... | 6,866,877 | 3,773,836 | 9,504,408 | 20,145,121 |
| 1875... | 6,281,712 | 2,834,605 | 10,596,155 | 19,712,472 |
| 1876. . | 6,221,934 | 3,854,919 | 8,424,158 | 18,501,311 |
| 1877... | 8,195,042 | 4,332,760 | 8,300,377 | 20,828,179 |
| 1878... | 6,282,226 | 3,237,449 | 8,085,587 | 17,605,262 |
| 1879.. | 8,960,329 | 4,595,567 | 12,586,293 | 26,142,689 |
| 1880... | 7,554,742 | 4,463,221 | 11,419,279 | 23,437,242 |
| 1881... | 9,253,958 | 5,294,676 | 13,951,383 | 28,500,016 |
| 1882... | 9,459,288 | 5,689 437 | 13,971,371 | 29,120,096 |

## ANTHRACITE COAL AREAS OWNED BY THE SEVERAL COMPANIES IN THE DIFFERENT COAL FIELDS AND THE PER CENT. OF THE WHOLE IN TONS.

[*From Mr. P. W. Sheafer's Diagram.*]

| Company. | Schuylkill. | | Middle. | | Wyoming. | |
|---|---|---|---|---|---|---|
| | Acres. | Per Cent | Acres. | Per Cent | Acres. | Per Cent |
| Lehigh Valley | ..... | ..... | 18,036 | 24 | 6,934 | 4 |
| Lehigh and Wilkesbarre | 7,600 | 8 | 7,000 | 8 | 7,400 | 5 |
| Delaware and Hudson | ..... | ..... | ..... | ..... | 20,042 | 12 |
| Delaware, Lack. & Western | ..... | ..... | ..... | ..... | 3,500 | 3 |
| Pennsylvania Coal Co | ..... | ..... | ..... | ..... | 10,000 | 6 |
| Phil. & Read. Coal & Iron Co. | 65,306 | 70 | 23,250 | 32 | ..... | ..... |
| Pennsylvania Railroad Co | 6,000 | 6 | 9,000 | 9 | 5,823 | 6 |
| Girard Estate | ..... | ..... | 6,000 | 8 | ..... | ..... |
| Gilbert & Co | ..... | ..... | 1,373 | 2 | ..... | ..... |
| Alliance Coal Mining Co | 3,172 | 3 | ..... | ..... | ..... | ..... |
| All others | 11,362 | 13 | 15,981 | 17 | 73,021 | 64 |
| Total | 93,440 | 100 | 80,640 | 100 | 126,720 | 100 |

# ANTHRACITE COAL TONNAGE OF THE DIFFERENT TRANSPORTATION COMPANIES FROM 1870 TO 1882.

COMPILED UPON THE BASIS OF DISTRIBUTION ESTABLISHED BY THE ANTHRACITE BOARD OF CONTROL FOR 1878.

| Year..... | Phila & Reading R R Co..... | Lehigh Valley R R Co..... | Cent'l R R Co of N J | Del, Lack & West'n R. R. Co..... | Del & Hud Can'l Co | Penna R R Co..... | Penna Coal Co..... | N Y L E & W R R... | Total..... ..... |
|---|---|---|---|---|---|---|---|---|---|
| 1870 | 4,169,707 | 3,608,587 | 1,606,469 | 2,117.612 | 2,318,073 | 1,225,733 | 1,136,010 | ..... | 16,182,191 |
| 1871 | 5,330,863 | 5,880,263 | 1,985,550 | 1,730,242 | 1,955,737 | 1,922,835 | 848,635 | 55,596 | 15,699,721 |
| 1872 | 5,645,103 | 3,850,118 | 2,253,614 | 2,520,330 | 2,882,479 | 1,168,084 | 266,762 | 83,288 | 19,669,778 |
| 1873 | 5,868,848 | 4,121,734 | 2,698.119 | 2,952,941 | 2,732,267 | 1,519,711 | 1,297,604 | 36,728 | 21,227,952 |
| 1874 | 5.568,601 | 3,989,821 | 2,706,007 | 2,353,539 | 2,290,791 | 1,642,474 | 1,396,326 | 197,562 | 20,145,121 |
| 1875 | 4 782,311 | 3,285,225 | 2,465,902 | 2,833,670 | 2,843,229 | 1,772,719 | 1,426,377 | 303,039 | 19,712,472 |
| 1876 | 4,931,754 | 3,985,351 | 2,778,096 | 1,998,654 | 1,809,190 | 1,623,335 | 1,143,922 | 230,709 | 18,501,011 |
| 1877 | 6,842,105 | 4,447,881 | 2,837,500 | 2,089,523 | 1,787,470 | 1,530,594 | 1,118,011 | 175,095 | 20,828,179 |
| 1878 | 5,112,219 | 3,403,318 | 2,264,979 | 2,180,673 | 52,046,23 | 1,362,674 | 957,032 | 278,132 | 17,605,262 |
| 1879 | 7,442,617 | 4,405,958 | 3,825,553 | 3,867,405 | 3,014,117 | 1,682,106 | 1,427,150 | 477,783 | 26,142,689 |
| 1880 | 5,933,923 | 4,394,533 | 3,470,141 | 3,550,348 | 2,674,705 | 1,864,032 | 1,138,466 | 411,094 | 23,427,242 |
| 1881 | 6,940,283 | 5,721,870 | 4.085,424 | 4,388,970 | 3,211,196 | 2,211,363 | 1,475,380 | 465,230 | 28,500,016 |
| 1882 | 7,000,113 | 5,933,740 | 4,211,052 | 4,638,717 | 3,203,168 | 2,332,974 | 1,469,821 | 330,511 | 29,120,096 |

## LOWEST AND HIGHEST PRICES OF ANTHRACITE COAL, BAR IRON AND SCOTCH PIG IRON, IN THE NEW YORK MARKET, FOR FIFTY-SEVEN YEARS.—1825—1881.

[*From Spofford's American Almanac*]

| Year. | Anthracite Coal. Ton. | | Iron, Bar. Ton. | | Iron. Scotch Pig. | |
|---|---|---|---|---|---|---|
| | L. | H. | L. | H. | L. Ton | H. |
| 1825 | $8 00 | $11 00 | $85 00 | $120 00 | $35 00 | $75 00 |
| 1826 | 11 00 | 12 00 | 85 00 | 100 00 | 50 00 | 70 00 |
| 1827 | 10 50 | 12 50 | 77 00 | 95 00 | 50 00 | 55 00 |
| 1828 | 10 00 | 12 00 | 77 50 | 82 50 | 50 00 | 55 00 |
| 1829 | 10 00 | 12 00 | 72 50 | 82 50 | 40 00 | 55 00 |
| 1830 | 7 00 | 12 00 | 72 50 | 77 50 | 40 00 | 50 00 |
| 1831 | 6 00 | 9 00 | 70 00 | 80 00 | 40 00 | 47 50 |
| 1832 | 8 50 | 16 00 | 70 00 | 75 00 | 40 00 | 47 50 |
| 1833 | 5 50 | 10 00 | 71 00 | 75 00 | 37 50 | 47 50 |
| 1834 | 5 50 | 6 50 | 67 00 | 75 00 | 37 50 | 48 00 |
| 1835 | 5 50 | 9 00 | 67 50 | 75 00 | 38 00 | 42 50 |
| 1836 | 7 00 | 11 00 | 75 00 | 105 00 | 38 00 | 62 50 |
| 1837 | 8 50 | 11 00 | 85 00 | 105 00 | 40 00 | 70 00 |
| 1838 | 7 00 | 9 50 | 85 00 | 97 50 | 37 50 | 55 00 |
| 1839 | 6 50 | 9 00 | 82 50 | 95 00 | 37 50 | 45 00 |
| 1840 | 6 00 | 8 50 | 70 00 | 82 50 | 32 50 | 40 00 |
| 1841 | 6 50 | 9 00 | 60 00 | 75 00 | 32 00 | 37 50 |
| 1842 | 5 00 | 9 00 | 50 00 | 62 50 | 23 50 | 35 00 |
| 1843 | 4 50 | 6 00 | 55 00 | 60 00 | 22 50 | 32 00 |
| 1844 | 4 25 | 6 00 | 57 00 | 65 00 | 30 00 | 35 00 |
| 1845 | 4 50 | 6 00 | 62 50 | 85 00 | 30 00 | 52 50 |
| 1846 | 5 00 | 7 00 | 75 00 | 80 00 | 35 00 | 42 50 |
| 1847 | 5 00 | 7 00 | 70 00 | 77 50 | 30 00 | 42 50 |
| 1848 | 4 50 | 6 00 | 50 00 | 70 00 | 25 00 | 37 50 |
| 1849 | 5 00 | 6 00 | 40 00 | 55 00 | 22 50 | 27 50 |
| 1850 | 5 00 | 7 00 | 40 00 | 45 00 | 21 00 | 24 00 |
| 1851 | 4 25 | 7 00 | 33 50 | 41 00 | 19 00 | 25 00 |
| 1852 | 5 00 | 7 00 | 34 00 | 55 00 | 19 00 | 31 00 |
| 1853 | 5 00 | 7 00 | 55 00 | 75 00 | 28 50 | 38 00 |
| 1854 | 6 00 | 7 50 | 62 50 | 77 50 | 32 00 | 42 50 |
| 1855 | 5 50 | 7 50 | 55 00 | 65 00 | 26 50 | 37 00 |
| 1856 | 5 50 | 6 50 | 50 00 | 65 00 | 29 00 | 37 00 |
| 1857 | 6 00 | 7 00 | 52 00 | 62 50 | 28 00 | 37 50 |
| 1858 | 5 00 | 6 00 | 44 00 | 55 00 | 22 00 | 27 00 |
| 1859 | 5 25 | 5 50 | 42 50 | 50 00 | 22 00 | 31 50 |
| 1860 | 5 50 | 6 00 | 41 00 | 44 00 | 20 50 | 27 00 |
| 1861 | 4 20 | 6 00 | 38 00 | 50 00 | 20 00 | 24 50 |
| 1862 | 4 25 | 8 50 | 50 00 | 70 00 | 21 00 | 33 00 |

| Year. | Anthracite Coal. Ton. L. | Anthracite Coal. Ton. H. | Iron, Bar. Ton. L. | Iron, Bar. Ton. H. | Iron. Scotch Pig. L. Ton. | Iron. Scotch Pig. H. |
|---|---|---|---|---|---|---|
| 1863 | $7 00 | $11 00 | $65 00 | $76 00 | $32 50 | $45 00 |
| 1864 | 9 00 | 15 00 | 105 00 | 220 00 | 43 00 | 80 00 |
| 1865 | 8 50 | 13 50 | 100 00 | 130 00 | 40 00 | 55 00 |
| 1866 | 8 50 | 13 00 | 94 00 | 115 00 | 42 00 | 55 00 |
| 1867 | 6 50 | 8 50 | 80 00 | 100 00 | 38 00 | 49 00 |
| 1868 | 6 50 | 11 50 | 80 00 | 95 00 | 35 00 | 45 75 |
| 1869 | 6 50 | 10 50 | 85 00 | 95 00 | 34 50 | 45 00 |
| 1870 | 4 50 | 8 50 | 70 00 | 90 00 | 31 00 | 37 00 |
| 1871 | 5 00 | 13 00 | 70 00 | 95 00 | 30 00 | 39 00 |
| 1872 | 3 75 | 6 25 | 85 00 | 120 00 | 33 50 | 61 00 |
| 1873 | 5 00 | 6 50 | 75 00 | 110 00 | 37 00 | 52 00 |
| 1874 | 4 55 | 5 55 | 55 00 | 80 00 | 33 00 | 45 00 |
| 1875 | 4 40 | 5 55 | 50 00 | 62 50 | 29 00 | 41 00 |
| 1876 | 3 75 | 5 55 | 40 00 | 54 00 | 27 50 | 34 00 |
| 1877 | 3 25 | 3 75 | 44 80 | 48 72 | 25 00 | 28 00 |
| 1878 | 2 75 | 4 50 | 42 50 | 45 00 | 21 50 | 26 50 |
| 1879 | 2 15 | 3 25 | 45 00 | 78 50 | 19 00 | 30 50 |
| 1880 | 3 50 | 4 45 | 46 00 | 76 00 | 20 00 | 40 00 |
| 1881 | 4 00 | 4 65 | 53 75 | 65 00 | 22 00 | 26 00 |

# COAL DEALERS' COMPUTING TABLE FOR ASCERTAINING THE PRICE ON ANY NUMBER OF POUNDS AT A GIVEN PRICE PER TON OF 2000 POUNDS.

FRACTIONS OF A TON.

*Prepared by Whitney, McCreary and Kemmerer, Philadelphia.*

| Lbs. | $2 75 | $3 00 | $3 25 | $3 50 | $3 75 | $4 00 | $4 25 | $4 50 | $4 75 | $5 00 | $5 25 | $5 50 | $5 75 | $6 00 | $6 25 | $6 50 | $6 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 01 | 02 | 02 | 02 | 02 | 02 | 02 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 |
| 20 | 03 | 03 | 03 | 04 | 04 | 04 | 05 | 05 | 05 | 05 | 06 | 06 | 06 | 06 | 06 | 07 | 07 |
| 30 | 04 | 05 | 05 | 05 | 06 | 06 | 07 | 07 | 07 | 08 | 08 | 08 | 09 | 09 | 09 | 10 | 10 |
| 40 | 06 | 06 | 07 | 07 | 08 | 08 | 09 | 09 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 13 | 14 |
| 50 | 07 | 08 | 08 | 09 | 09 | 10 | 11 | 12 | 12 | 13 | 13 | 14 | 15 | 15 | 16 | 16 | 17 |
| 60 | 08 | 09 | 10 | 11 | 11 | 12 | 13 | 14 | 15 | 15 | 16 | 17 | 18 | 18 | 19 | 20 | 20 |
| 70 | 10 | 11 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 19 | 20 | 21 | 22 | 23 | 24 |
| 80 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 90 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 31 |
| 100 | 14 | 15 | 16 | 18 | 19 | 20 | 22 | 23 | 24 | 25 | 27 | 28 | 29 | 30 | 31 | 33 | 34 |
| 200 | 28 | 30 | 33 | 35 | 38 | 40 | 43 | 45 | 48 | 50 | 53 | 55 | 58 | 60 | 63 | 65 | 68 |
| 300 | 41 | 45 | 49 | 53 | 56 | 60 | 64 | 68 | 72 | 75 | 79 | 83 | 87 | 90 | 94 | 98 | 1 01 |
| 400 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 1 00 | 1 05 | 1 10 | 1 15 | 1 20 | 1 25 | 1 30 | 1 35 |
| 500 | 69 | 75 | 81 | 88 | 94 | 1 00 | 1 07 | 1 13 | 1 19 | 1 25 | 1 32 | 1 38 | 1 44 | 1 50 | 1 56 | 1 63 | 1 69 |
| 600 | 83 | 90 | 98 | 1 05 | 1 13 | 1 20 | 1 28 | 1 35 | 1 43 | 1 50 | 1 58 | 1 65 | 1 73 | 1 80 | 1 88 | 1 95 | 2 03 |
| 700 | 96 | 1 05 | 1 14 | 1 23 | 1 31 | 1 40 | 1 49 | 1 58 | 1 67 | 1 75 | 1 84 | 1 93 | 2 02 | 2 10 | 2 19 | 2 28 | 2 36 |
| 800 | 1 10 | 1 20 | 1 30 | 1 40 | 1 50 | 1 60 | 1 70 | 1 80 | 1 90 | 2 00 | 2 10 | 2 20 | 2 30 | 2 40 | 2 50 | 2 60 | 2 70 |
| 900 | 1 24 | 1 35 | 1 46 | 1 58 | 1 69 | 1 80 | 1 92 | 2 03 | 2 14 | 2 25 | 2 37 | 2 48 | 2 59 | 2 70 | 2 81 | 2 93 | 3 04 |
| 1000 | 1 38 | 1 50 | 1 63 | 1 75 | 1 88 | 2 00 | 2 13 | 2 25 | 2 38 | 2 50 | 2 63 | 2 75 | 2 88 | 3 00 | 3 13 | 3 25 | 3 38 |
| 1100 | 1 51 | 1 65 | 1 79 | 1 93 | 2 06 | 2 20 | 2 34 | 2 48 | 2 62 | 2 75 | 2 89 | 3 03 | 3 17 | 3 30 | 3 44 | 3 58 | 3 72 |
| 1200 | 1 65 | 1 80 | 1 95 | 2 10 | 2 25 | 2 40 | 2 55 | 2 70 | 2 85 | 3 00 | 3 15 | 3 30 | 3 45 | 3 60 | 3 75 | 3 90 | 4 05 |
| 1300 | 1 79 | 1 95 | 2 11 | 2 28 | 2 44 | 2 60 | 2 77 | 2 93 | 3 09 | 3 25 | 3 42 | 3 58 | 3 75 | 3 90 | 4 07 | 4 23 | 4 39 |
| 1400 | 1 93 | 2 10 | 2 28 | 2 45 | 2 63 | 2 80 | 2 98 | 3 15 | 3 33 | 3 50 | 3 68 | 3 85 | 4 03 | 4 20 | 4 38 | 4 55 | 4 73 |
| 1500 | 2 06 | 2 25 | 2 44 | 2 63 | 2 81 | 3 00 | 3 19 | 3 38 | 3 57 | 3 75 | 3 94 | 4 13 | 4 32 | 4 50 | 4 69 | 4 88 | 5 07 |
| 1600 | 2 20 | 2 40 | 2 60 | 2 80 | 3 00 | 3 20 | 3 40 | 3 60 | 3 80 | 4 00 | 4 20 | 4 40 | 4 60 | 4 80 | 5 00 | 5 20 | 5 40 |
| 1700 | 2 34 | 2 55 | 2 76 | 2 98 | 3 19 | 3 40 | 3 62 | 3 83 | 4 04 | 4 25 | 4 47 | 4 68 | 4 89 | 5 10 | 5 32 | 5 53 | 5 74 |
| 1800 | 2 48 | 2 70 | 2 93 | 3 15 | 3 38 | 3 60 | 3 83 | 4 05 | 4 28 | 4 50 | 4 73 | 4 95 | 5 18 | 5 40 | 5 63 | 5 85 | 6 08 |
| 1900 | 2 61 | 2 85 | 3 09 | 3 33 | 3 56 | 3 80 | 4 04 | 4 28 | 4 52 | 4 75 | 4 99 | 5 23 | 5 47 | 5 70 | 5 94 | 6 18 | 6 42 |

# RATING OF COLLIERIES SHIPPING BY PHILADELPHIA & READING RAILROAD.

*East Mahanoy, Mahanoy and Shamokin, and Mine Hill, North District. J. H. OLHAUSEN, Supt.*

| Name of Colliery. | Name of Operator. | Date of Last Rating | Rated Capacity Per Day in Cars. |
|---|---|---|---|
| North Star | Reynolds, Roberts & Co | 11. 4, 80 | 38 |
| Schuylkill | P. & R. C. & I. Co | 4, 26, 81 | 86 |
| North Mahanoy | " " | 4, 30, 78 | 113 |
| Mahanoy City | " " | 3, 7, 78 | 110 |
| Tunnel Ridge | " " | 4, 28, 81 | 91 |
| St. Nicholas | " " | 12, 9, 79 | 111 |
| Coal Run | Suffolk Coal Co | 9, 21, 80 | 140 |
| Ellangowan | P. & R. C. & I. Co | 3, 3, 80 | 240 |
| Knickerbocker | " " | 11, 8, 79 | 156 |
| Bear Run | " " | 4, 9, 80 | 104 |
| Boston Run | " " | 4, 9, 80 | 102 |
| Draper | | 6, 30, 81 | 125 |
| Gilberton | P. & R. C. & I. Co | 4, 27, 81 | 82 |
| Lawrence | Lawrence, Merkel & Co | 4, 20, 80 | 141 |
| West Bear Ridge | Myers, McCreary & Co | 4, 19, 80 | 113 |
| Colorado | Phila. Coal Co | 10, 17, 78 | 150 |
| Shenandoah | " " | 10, 18, 78 | 144 |
| William Penn | Wm. Penn Coal Co | 3, 16, 80 | 210 |
| Turkey Run | P. & R. C. & I. Co | 4, 7, 80 | 122 |
| West Shenandoah | " " | 4, 15, 80 | 130 |
| Kohinoor | R. Heckscher & Co | 9, 15, 80 | 200 |
| Shenandoah City | P. & R. C. & I. Co | 9, 24, 79 | 64 |
| Plank Ridge | " " | 5, 18, 80 | 125 |
| Kehley Run | Thomas Coal Co | 11, 4, 78 | 190 |
| Conner | P. & R. C. & I. Co | 5, 12, 80 | 140 |
| Girard Mammoth | " " | 11, 25, 79 | 55 |
| Cuyler | S. M. Heaton & Co | 3, 4, 80 | 190 |
| Preston, No. 2 | P. & R. C. & I. Co | 10, 23, 78 | 120 |
| Continental | Lehigh Valley Coal Co | 10, 21, 78 | 137 |
| Centralia | " " | 11, 11, 78 | 121 |
| Hazel Dell | Sykes & Jones | 11, 1, 78 | 28 |
| North Ashland | P. & R. C. & I. Co | 5, 26, 80 | 135 |
| Bast | " " | 3, 14, 79 | 150 |
| Big Mine Run | J. Taylor & Co | 1, 21, 80 | 160 |
| Tunnel | P. & R. C. & I. Co | 2, 14, 81 | 16 |
| Girard | " " | 5, 26, 76 | 120 |
| Preston, No. 3 | " " | 6, 3, 80 | 126 |
| Reliance | " " | 6, 7, 80 | 126 |
| Mt. Carmel | Montelius, Robertson & Co | 1, 24, 81 | 136 |
| Monitor | Geo. W. Johns & Bro | 11, 11, 79 | 144 |
| Merriam | P. & R. C. & I. Co | 4, 5, 80 | 125 |
| Potts | " " | 4, 9, 78 | 140 |
| Keystone | " " | 2, 1, 81 | 25 |
| Locust Spring | " " | 5, 17, 80 | 132 |
| Ben Franklin | Douty & Baumgardner | 5, 10, 78 | 92 |

| Name of Colliery. | Name of Operator. | Date of Last Rating. | Rated Capacity Per Day in Cars. |
|---|---|---|---|
| Enterprise | Enterprise Coal Co | 2, 10, 81 | 157 |
| Excelsior | Excelsior Coal M'g Co | 11, 2, 76 | 110 |
| Greenback | H. J. Toudy | 8, 16, 80 | 57 |
| Buck Ridge | May, Audenried & Co | 11, 16, 78 | 114 |
| Big Mountain | Patterson, Llewellyn & Co. | 5, 10, 80 | 166 |
| Bear Valley | P. & R. C. & I. Co | 10, 24, 78 | 155 |
| Burnside | " " | 5, 8, 77 | 81 |
| North Franklin, No. 1 | " " | 4, 3, 77 | 57 |
| George Fales | " " | 11, 26, 79 | 52 |
| Stanton | Miller, Hoch & Co | 4, 2, 80 | 116 |
| Indian Ridge | P. & R. C. & I. Co | 5, 12, 80 | 180 |
| Elmwood | " " | 6, 7, 78 | 82 |
| Staffordshire | Jones, Ward & Co | 1, 20, 80 | 20 |
| East Bear Ridge | Myers, McCreary & Co | 4, 2, 80 | 100 |
| Hammond | P. & R. C. & I. Co | 5, 12, 80 | 100 |
| Locust Gap | Graeber & Shepp | 5, 19, 78 | 140 |
| N. Franklin, No. 2 | P. & R. C. & I. Co | 5, 25, 80 | 112 |
| Mt. Carmel Shaft | " " | 4, 13, 80 | 200 |
| Webster | L. S. Baldwin | 10, 13, 80 | 35 |
| Oakdale | E. L Powell | 6, 8, 81 | 24 |
| Cambridge | Cambridge Coal Co | 10, 8, 77 | 7 |
| Stirling | Kendrick & Co | 11, 26, 79 | 117 |
| Franklin | S. S. Bickel | 1, 5, 81 | 60 |
| Henry Clay, No 1 | J. Langdon & Co | 11, 8, 78 | 152 |
| Carson | P. Goodwill | 10, 24, 78 | 25 |
| Peerless | Cruikshank & Emes | 9, 16, 78 | 74 |
| Laurel Ridge | John A. Dutter | 4, 1, 80 | 30 |
| Hillside | Smith, Williams & Co | 1, 25, 81 | 22 |
| Beechwood | P. & R. C. & I. Co | 11, 18, 79 | 90 |
| Wadesville | " " | 12, 19, 79 | 177 |
| Monitor | John Denning | 10, 12, 77 | 13 |
| Eagle | Geo. W. Johns & Bro | 4, 24, 78 | 74 |
| St. Clair | Jos. Atkinson & Co | 10, 28, 78 | 7 |
| Eagle Hill | P. & R. C. & I. Co | 12, 10, 79 | 102 |
| Coal Hill | R. Holahan & Bro | 5, 20, 78 | 9 |
| Palmer Vein | Alliance Coal Mining Co | 5, 1, 76 | 61 |
| Pottsville | P. & R. C. & I. Co | 12, 18, 79 | 96 |
| Pine Dale | Louis Lorenz | 2, 1, 81 | 30 |
| West Lehigh | Wood & Pearce | 8, 22, 78 | 26 |
| East Lehigh | Mitchel & Symen | 8, 5, 78 | 8 |
| | | Total | 8729 |

The facts considered in rating collieries are :

*First.*—The number of mine cars that can be produced daily and their capacity in tons.

*Second.*—The capacity of the engines to hoist the coal produced.

*Third.*—The capacity of the breaker to prepare the coal.

## MINE HILL, SOUTH DISTRICT.

*A. Hesser, Superintendent.*

| Name of Colliery. | Name of Operator. | Rated Capacity Per Day in Cars. |
|---|---|---|
| Mine Hill Gap | P. & R. C. & I. Co | 106 |
| Richardson | " " | 128 |
| Glendower | " " | 85 |
| Phœnix Park, No. 2 | " " | 72 |
| Forestville | " " | 70 |
| Otto | " " | 100 |
| Swatara | " " | 69 |
| Middle Creek Shaft | " " | 100 |
| East Franklin | " " | 65 |
| Thomaston | " " | 125 |
| Ellsworth | John R. Davis | 25 |
| Wolf Creek Big Diamond | E. Thomas | 34 |
| Black Heath | Wm. H. Harris | 45 |
| Black Mine | H. A. Moodie & Co | 35 |
| Wolf Creek Big Diamond | James Donahoe | 20 |
| Phœnix Park, No. 3 | P. & R. C. & I. Co | 92 |
| Wolf Creek | Edward Hoskins | 8 |
| Dundas, No 7 | Davis & Co | 3 |
| | Total | 1182 |

## SCHUYLKILL AND SUSQUEHANNA, AND LEBANON AND TREMONT BRANCHES.

*H. W. Tracy, Superintendent.*

| Name of Colliery. | Name of Operator. | Rated Capacity Per Day in Cars. |
|---|---|---|
| Brookside | P. & R. C. & I. Co | 450 |
| Colket | " " | 102 |
| Rausch Creek | Miller, Graeff & Co | 140 |
| Lincoln | Levi Miller & Co | 200 |
| Kalmia | Phillips & Sheaffer | 200 |
| | Total | 1092 |

Summary of PERSONS EMPLOYED, TONS of COAL MINED, POWDER USED, &c., in and about the Coal Mines of Pennsylvania, for the year 1881.

| DISTRICTS. | INSPECTORS. | No. of collieries in operation. | No. of Employees. Inside. | Outside. | Total. | No. of tons of Coal Produced including that sold and consumed at mines. | Tons of Coal mined to each Employe. | Average No. of days worked. | No of Kegs of Powder Used. | Tons of Coal mined per keg of Powder Used. | No. of Horses and Mules. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTHRACITE. | | | | | | | | | | | |
| Pottsville, or First Sch. District, | Samuel Gay | *54 | 4,006 | 2,491 | 6,497 | 1,829,655 | 281·10 | 202½ | 33,493 | 54·8 | |
| Shenandoah, or Second Sch. District, | Robert Mauchline | 46 | 5,917 | 4,994 | 10,911 | 4,504,623 | 412·01 | 215½ | 97,391 | 46·25 | 841 |
| Shamokin, or Third Sch. District, | James Ryan | 50 | 6,990 | 4,885 | 11,875 | 4,432,600 | 373· | 217¾ | 84,578 | 52·48 | 1,419 |
| Middle Dist. of Carbon and Luzerne, | G. M. Williams | 51 | 10,964 | 5,844 | 16,808 | 7,021,508 | 417·74 | 221½ | †177,000 | 40· | 1,829 |
| Eastern Dist. of Carbon and Luzerne, | Patrick Blewitt | 82 | 12,271 | 6,569 | 18,840 | 7,711,660 | 409·32 | 232⅞ | ‡ 94,274 | § 28· | 2,460 |
| South Dist. of Carbon and Luzerne, | James E. Roderick | 56 | 6,387 | 4,713 | 11,100 | 5,037,948 | 453·87 | 214¼ | 88,917 | 56·65 | |
| | Total Anthracite, | 339 | 46,535 | 29,496 | 76,031 | 30,537,994 | 391·17 | 217 | | | |
| BITUMINOUS. | | | | | | | | | | | |
| First District, | James Louttit | 181 | 11,720 | 3,258 | 14,978 | 8,272,605 | 552·31 | 172 | | | 1,086 |
| Second District, | John J. Davis | 120 | 10,619 | 2,230 | 12,849 | 6,583,200 | 512·35 | 231 | | | 1,058 |
| Third District, | Thomas K. Adams | 96 | 6,407 | 833 | 7,240 | 4,202,000 | 580·4 | 198 | | | 573 |
| Fourth District, | Roger Hampson | 61 | 4,615 | 1,182 | 5,797 | 2,908,219 | 501·67 | 244 | | | 638 |
| | Total Bituminous. | 458 | 33,361 | 7,503 | 40,864 | 21,966,024 | 536·68 | 211½ | | | |
| | Grand Total, | 797 | 79,896 | 36,999 | 116,895 | 52,504,018 | 463·92 | 214¼ | | | |
| | Increase or Decrease over 1880, | ‖ 59 | | | ‖ 7,136 | ‖10,057,310 | ‖76·57 | ‖35 | | | |

NOTE.—The First Bitumiuous District embraces that part of Allegheny county lying south of the Ohio and Monongahela rivers, togther with the counties of Bedford, Fayette, Greene, Somerset and Washington. The Second District embraces that portion of Allegheny county lying north of the Ohio, Monongahela and Youghiogheny rivers, and the counties of Armstrong, Beaver, Butler, Indiana and Westmoreland. The Third District embraces the counties of Cameron, Clarion, Clearfield, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Veuango and Warren. The Fourth District the counties of Blair, Bradford, Cambria, Centre, Clinton, Huntingdon, Lycoming, Potter, Sullivan and Tioga.

*Twenty-oue of these shipped less than 5,000 tons each.

†The powder used at the collieries of the Delaware and Hudson Coal Company was not reported, but is estimated in this total.

‡The Pennsylvania Coal Company, The Delaware, Laekawanna and Western Railroad Company and the Delaware and Hudson Canal Company did not report their eonsumption of powder. This is the amount consumed by the miscellaneons companies in the district.

§This is the average for the miscellaneous companies in the district only.

‖Inerease.

Summary of FATAL AND NON-FATAL ACCIDENTS in and about the Coal Mines of Pennsylvania for the year 188

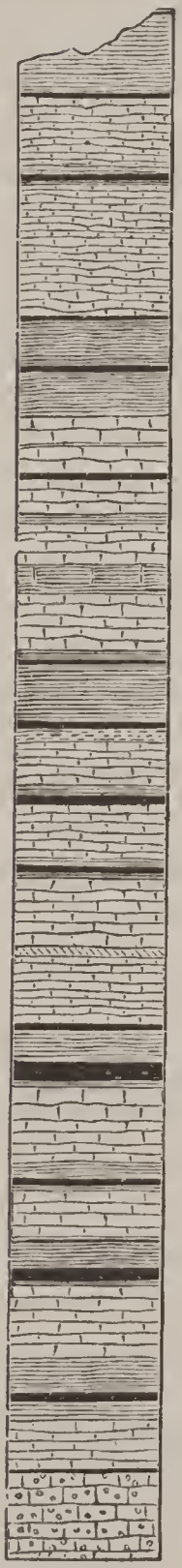
| DISTRICTS. | Falls. | | | Explosions of Gas. | | | Explosions of Powder. | | | Mine Cars & Mach'y | | | Miscellaneous. | | | Total Accidents. | | Tons of Coal Mined per Fatal Accident. | No. of Tons Mined per Casualty. | No. Employes to each Casualty. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal. | Non-Fatal. | Total. | Fatal. | Non-Fata | Total. | Fatal. | Non-Fatal. | Total. | Fatal. | Non-Fatal. | Total. | Fatal. | Non-Fatal. | Total. | Fatal. | Non-Fatal. | | | |
| ANTHRACITE. | | | | | | | | | | | | | | | | | | | | |
| Pottsville, or First Sch. District, | 6 | 68 | 74 | 2 | 41 | 43 | 0 | 10 | 10 | 7 | 36 | 43 | 3 | 18 | 21 | 18 | 173 | 101,647 | 9,579 35 | 34· |
| Shenandoah, or Second Sch. District, | 16 | 68 | 84 | *3 | 15 | 18 | 2 | 6 | 8 | 10 | 47 | 57 | 3 | 13 | 16 | 34 | 149 | 132,488 | 24,615·43 | 59·62 |
| Shamokin, or Third Sch. District, | 21 | 37 | 58 | 4 | 24 | 28 | 3 | 10 | 13 | 10 | 31 | 41 | 10 | 45 | 55 | 48 | 147 | 92,346 | 22,731·28 | 60·9 |
| Middle District of Carbon & Luzerne | 28 | 43 | 71 | 10 | 24 | 34 | 7 | 25 | 32 | 10 | 44 | 54 | 24 | 34 | 58 | 79 | 170 | 88,879 | 28,198·82 | 67·5 |
| Eastern District of Carbon & Luzerne | 22 | 42 | 64 | 5 | 6 | 11 | 3 | 8 | 11 | 13 | 33 | 46 | 4 | 18 | 22 | 47 | 107 | 164,078 | 50,075·71 | 122·34 |
| South District of Carbon & Luzerne | 24 | 25 | 49 | 3 | 11 | 14 | 1 | 5 | 6 | 15 | 35 | 50 | 4 | 12 | 16 | 47 | 88 | 107,190 | 37,318 13 | 82·22 |
| Total Anthracite, | 117 | 283 | 400 | 27 | 121 | 148 | 16 | 64 | 80 | 65 | 226 | 291 | 48 | 140 | 188 | 273 | 834 | ‡114,438 | 28,753·12 | 71·1 |
| BITUMINOUS. | | | | | | | | | | | | | | | | | | | | |
| First, | 20 | 18 | 38 | 1 | 2 | 3 | ... | 2 | 2 | 2 | 7 | 9 | ... | 14 | 14 | 23 | 43 | 359,678 | 125,342·5 | 227· |
| Second, | 9 | 28 | 37 | ..... | 8 | 8 | ... | ..... | ..... | 2 | 10 | 12 | 6 | 9 | 15 | 17 | 55 | 387,247 | 91,433·33 | 178·5 |
| Third, | 5 | 19 | 24 | ..... | ..... | ..... | ... | ..... | ..... | 1 | 12 | 13 | 2 | 7 | 9 | 8 | 38 | 500,000 | 91,348· | 157·4 |
| Fourth, | 6 | 19 | 25 | ..... | ..... | ..... | ... | 1 | 1 | 1 | 13 | 14 | 0 | 3 | 3 | 7 | 36 | 415,690 | 67,633· | 134·8 |
| Total Bituminous, | 40 | 84 | 124 | 1 | 10 | 11 | 0 | 3 | 3 | 6 | 42 | 48 | 8 | 33 | 41 | 55 | 172 | ‡415,656 | 93,939·21 | 174·4 |
| Grand Total, | 157 | 367 | 524 | 28 | 131 | 159 | 16 | 67 | 83 | 71 | 268 | 339 | 56 | 173 | 229 | 328 | 1,006 | ‖265,046 | 61,346.16 | 122·75 |
| Increase or Decrease over 1880. | ₹31 | ₹17 | ₹48 | ₹13 | ₹8 | ₹51 | ₹7 | ₹12 | ₹19 | | | | | | | ₹78 | ₹137 | †87,3·6 | ₹11,020· | |

*Two of these were suffocated. †This is the average decrease in tons mined per life lost for the whole State.
‡Average. ‖Grand Average. ₹Increase.

## ANALYTICAL TABLE OF AMERICAN COALS.

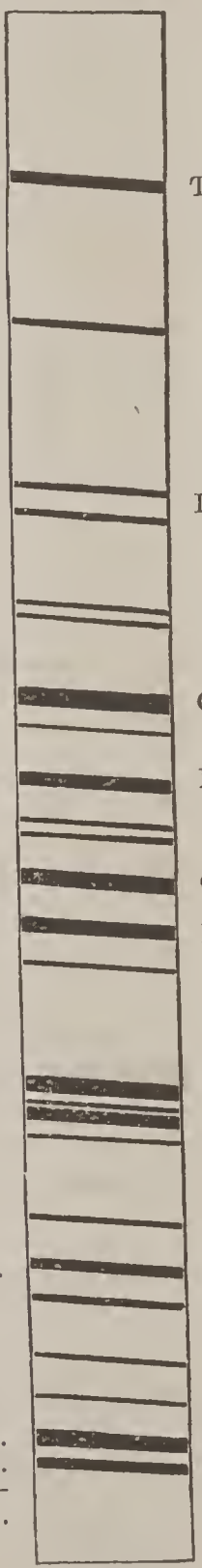
| VARIETY. | LOCALITY. | Fixed Carbon. | Ash. | Sulphur. | Volatile Combustible Matter. | Moisture. | Pounds of Water Evaporated by 1 lb of Coal. |
|---|---|---|---|---|---|---|---|
| ANTHRACITE. | | | | | | | |
| Free Burning | Northumberland Co., Pa. | 89·65 | 5·34 | 0·32 | 3·40 | 1·29 | 10·36 |
| Hard White Ash | Schuylkill Co., Pa. | 96·19 | 1·96 | 0·02 | 0·53 | 1·35 | ..... |
| Red Ash | " " | 83·61 | 11·25 | 0·03 | 3 6 | 1·5 | 11·70 |
| Semi-Bituminous | Broad Top Region Pa. | 74·65 | 7·50 | ..... | 17·55 | 0·30 | ..... |
| " " | Clearfield Co., Pa. | 74·28 | 3·25 | 0·43 | 21·36 | 0·67 | ..... |
| | | | | | | ..... | ..... |
| BITUMINOUS. | | | | | | | |
| Gas | Jefferson Co., Pa. | 53·68 | 4·19 | 2·04 | 38·72 | 1·36 | ..... |
| Caking | Connellsville Region, Pa. | 61·45 | 5·80 | 1·04 | 30·41 | 1·30 | ..... |
| Block | Mahoning Valley, Ohio. | 74·25 | 1·45 | 0·56 | 31·83 | 2·47 | ..... |
| Caking | Columbiana Co., Ohio. | 56·04 | 1·80 | 0·53 | 39·60 | 2·56 | ..... |
| Cannel | Boone Co., W. Virginia | 41·00 | 13·00 | ..... | 46·00 | ..... | ..... |
| ..... | D. Vein, West Kentucky. | 52·11 | 8·41 | 3·33 | 35·41 | 3·82 | ..... |
| Caking | Cahaba Region, Ala. | 64·36 | 2·96 | 0·53 | 31·78 | 0·38 | ..... |
| Block | Davies Co., Indiana. | 50 75 | 1·75 | ..... | 46·50 | 1·00 | ..... |
| Block | Big Muddy Coal, Illinois. | 60·80 | ..... | ..... | 31·20 | 6·50 | ..... |
| ..... | Macon Co., Missouri. | 43·50 | 3·70 | ..... | 40·75 | 12 05 | ..... |
| Rich Gas | Breckenridge Co., Ky. | 28·20 | 7·96 | ..... | 62·40 | 1·44 | ..... |
| Caking | Clay Co., Indiana. | 47·30 | 6·00 | ..... | 39·70 | 7·00 | ..... |
| Caking | Steubenville, Ohio. | 65 90 | 1·80 | ..... | 30·90 | 1·40 | ..... |

Vertical Section in the Southern Anthracite Coal Fields of Pennsylvania.



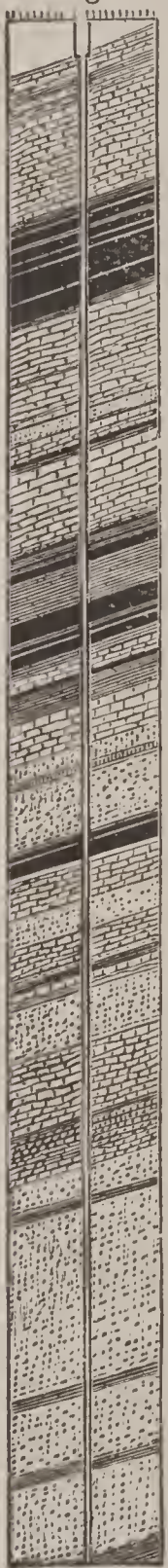
| | | |
|---|---|---|
| Red Ash Coal, | 3 ft. | Sandrock. |
| " " | 7 ft. | Gate. |
| " " | 3 ft. | Little Tracy. |
| " " | 6 ft. | Tracy. |
| " " | 6 ft. | Diamond. |
| " " | 3 ft. | Little Orchard. |
| " " | 6 ft. | Orchard. |
| Grey Ash Coal, | 10 ft. | Primrose. |
| White Ash Coal, | 5 ft. | Holmes. |
| " | 7 ft. | Seven Feet. |
| " " | 25 ft. | Mammoth. |
| " " | 6 ft. | Skidmore. |
| " " | 9 ft. | Buck Mountain. |
| Red Ash Coal, | 8 ft. | Lykens Valley upper. |
| " " | 3 ft. | Lykens Valley, lower. |
| Total Coal, | 107 ft. | |

## Vertical Section Anthracite Coal Measures Nanticoke Basin



| | | |
|---|---|---|
| Red Ash Coal, | 4 ft. 6 in. | Tracy. |
| Pink Ash Coal, | 4 ft. 4 in. | Diamond. |
| Grey Ash Coal, | 6 ft. 6 in. | Orchard. |
| White Ash Coal. | 7 ft. 2 in. | Hillman or Primrose. |
| " " " | 4 ft. 3 in. | Cooper } Baltimore, or |
| " " " | 5 ft. 9 in. | Bennet } Mammoth. |
| " " " | 12 ft. | Twin, Top Bench } Skid-<br>Twin, Bottom " } more. |
| " " " | 4 ft. 8 in. | Ross. |
| Red Ash Coal, | 7 ft. 0 in. | Buck Mountain. |
| " " " | 5 7t. 6 in. | Red Ash, Bench. |
| Total Coal, | 61 ft. 8 in. | |

Vertical Section at Crystal Ridge Colliery, Near Hazleton, Pa.



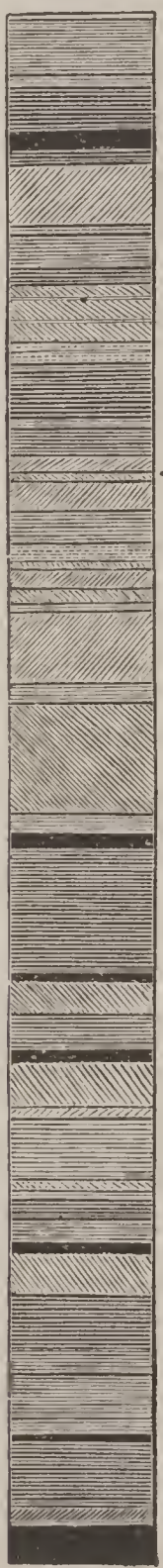
Mammoth Seam, 33 ft. — Dist. from Surface, 75 ft.

Wharton Seam, 8½ ft. — Dist. from Surface, 234 ft.

Buck Mt. Seam, 8 ft. — Dist. from Surface, 826 ft.

Total Coal, 49 ft. 6 in. — Total Depth, 640 ft. 7 in.

Vertical Section taken at Connellsville Coke and Iron Co.'s Shaft, No. 1, Leisenring, Dunbar Township, Fayette County, Pa.



Surface.

Black Slate, 3⅓ ft. — Dist. from Surface, 30 ft.

Coal, 2¼ ft. — Dist. from Surface, 197 ft.

Coal, ½ ft. — Dist. from Surface, 230 ft.

Coal, 2 ft. — Dist. from Surface, 246 ft.

Coal, ⅔ ft. — Dist. from Surface, 290 ft.

Coal, 1 ft. — Dist. from Surface, 34 ft. 8 in.

Dry Bone, or Wild Coal, 5 ft.

Connellsville Coke Coal, 10 ft. — Dist. from Surface, 371 ft. 11 in.

## ARITHMETICAL SIGNS USED IN THE POCKET BOOK.

$+$ signifies *plus*, or addition.
$-$ " *minus*, or subtraction.
$\times$ " multiplication.
$\div$ " division.
$: \; :: \; :$ " proportion.
$=$ " equality.
$\surd$ " square root.
$\sqrt[3]{}$ " cube root, &c.

Thus,

$5 + 3$, denotes that 3 is to be added to 5.
$6 - 2$, denotes that 2 is to be taken from 6.
$7 \times 3$, denotes that 7 is to be multiplied by 3.
$8 \div 4$, denotes that 8 is to be divided by 4.
$2 : 3 :: 4 : 6$, shows that 2 is to 3 as 4 is to 6.
$6 + 4 = 10$, shows that the sum of 6 and 4 is equal to 10.
$\surd 3$, denotes the square root of the number 3.
$\sqrt[3]{5}$, denotes the cube root of the number 5.
$7^2$, denotes that the number 7 is to be squared.
$8^3$, denotes that the number 8 is to be cubed.
$\overline{\qquad}$ The *Bar* denotes that the numbers or quantities are to be taken together : thus

$$\overline{6 - 2} + 8 = 12, \text{ or } 5 \times \overline{6 + 1} = 35.$$

The same may be expressed by the ( ) Parentheses ; as $(2 + 6) \times 4 = 32$.

A *Decimal Point* is a period ( · ) prefixed to a number to show that the number is less than unity (1) ; thus $\cdot 2 = \frac{2}{10}$ ; $\cdot 35 = \frac{35}{100}$ ; $5 \cdot 75 = 5\frac{75}{100}$ or $3\frac{3}{4}$ ; $1 \cdot 25 = 1\frac{25}{100}$ or $1\frac{1}{4}$ ; $\cdot 00375 = \frac{375}{100000}$, &c.

*Degrees* are expressed by writing ° over them, as 24° for 24 degrees.

*Minutes* are marked by an accent (′).

*Seconds* thus (″), &c. Thus 30° 40′ 4″ is read 30 degrees, 40 minutes and 4 seconds.

## ALGEBRAIC CHARACTERS.

Algebra is a method of investigating quantity by means of general characters called symbols. In addition to the arithmetical signs already given, the different letters of the alphabet are used to represent different quantities.

To illustrate algebraic symbols let $l$ denote the length, $b$ the breadth and $h$ the heighth of a mine car. If it be desired to divide the heighth into the product of the length and breadth, it is expressed as follows :

$$\frac{lb}{h}$$

When two or more letters are placed together without anything between them, it is understood that the quantities represented by those letters should be multiplied together. If $l$ represents 8 and $b$ 4, then 4 and 8 are multiplied together, thus : $4 \times 8 = 32$.

If it be desired to divide the heighth into the sum of the length and breadth, it is thus expressed :

$$\frac{l + b}{h}$$

The square of the length multiplied by the cube of the breadth, thus :

$$l^2 b \sqrt[3]{}$$

The square root of the length divided by the cube root of the breadth, thus :

$$\frac{\sqrt{l}}{\sqrt[3]{b}}$$

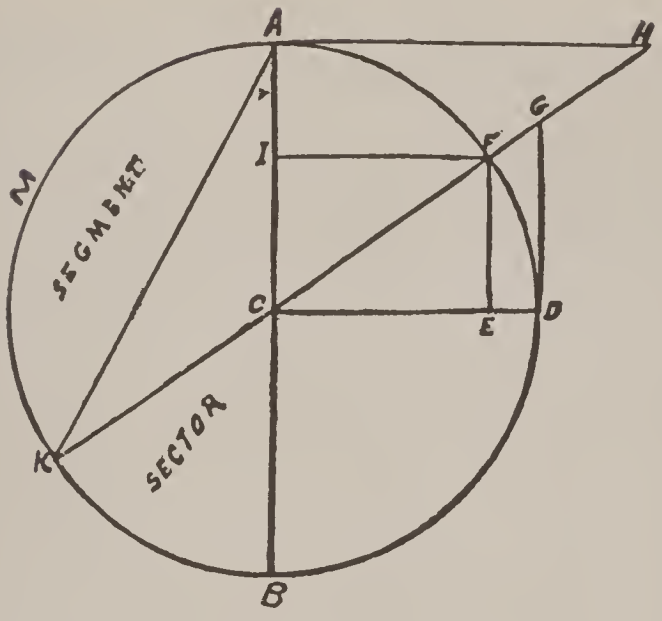
The square root of the difference of the length and breadth divided by the heighth, thus :

$$\frac{\sqrt{l - b}}{h}$$

The square root of the quotient of the sum and difference of the length and breadth, thus :

$$\sqrt{\frac{l + b}{l - b}}$$

## TERMS USED IN TRIGONOMETRY.




F. E. or I. C. =sine of angle F. C. E.
F. I. or C. E. =Cosine.
D. G. =Tangent.
A. H. =Co-tangent.
E. D. =Versed line.
A. I. =Coversine.
C. D. =Radius.

A. K. =Chord.
A. M. K. =Arc.
A. B. =Diameter.
*Segment* is the space included between the chord A. K. and the arc A. M. K.
*Sector* is the space included between the radii C. B. and C. K. and the arc, B. K.

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## TRIGONOMETRICAL EQUIVALENTS.

$\sqrt{(1-\sin^2)}$ =cos.
Sin. ÷ Tan. =Cos.
Sin. × Cot. =Cos.
Sin. ÷ Cos. =Tan.
Cos. ÷ Sin. =Cot.
Cos. ÷ Cot. =Sin.
Tan. ÷ Sin. =Sec.
Tan. ÷ Sec. =Sin.
Tan. × Cot. =Rad.

$\sqrt{(1-\mathrm{Cos}^2)}$ =Sin.
1 ÷ Cot. =Tan.
1 ÷ Sin. =Cosec.
1 ÷ Cos. =Sec.
1 ÷ Cosec. =Sin.
1 ÷ Sec. =Cos.
1 ÷ Tan. =Cot.
1 − Cos. =Versin.
1 − Sin. =Coversin.

## Natural Sines, &c.

| Deg. | Sine. | Cover. | Cosec. | Tan. | Cotan. | Secant | Vrsn. | Cosin. | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | ·00 | 1·00000 | infinite | ·0 | infinite | 1·00000 | ·0 | 1·00000 | 90 |
| 1 | ·01745 | ·98255 | 57·2987 | ·01746 | 57·2900 | 1 00015 | 00015 | ·99985 | 89 |
| 2 | ·03490 | ·96510 | 28·6537 | ·03492 | 28·6363 | 1·00061 | ·00061 | ·99939 | 88 |
| 3 | ·05234 | ·94766 | 19·1073 | ·05241 | 19·0811 | 1·00137 | ·00137 | ·99863 | 87 |
| 4 | ·06976 | ·93024 | 14·3356 | ·06993 | 14 3007 | 1 00244 | ·00244 | ·98756 | 86 |
| 5 | ·08716 | ·91284 | 11·4737 | ·08749 | 11·4301 | 1·00382 | 00381 | ·99619 | 85 |
| 6 | ·10453 | 89547 | 9·5668 | ·10510 | 9·5144 | 1·00551 | ·00548 | ·99452 | 84 |
| 7 | ·12187 | 87813 | 8·2055 | ·12278 | 8·1443 | 1 00751 | ·00745 | ·99255 | 83 |
| 8 | ·13917 | 86083 | 7·1853 | 14054 | 7·1154 | 1.00983 | ·00973 | ·99027 | 82 |
| 9 | ·15643 | 84357 | 6·3925 | 15838 | 6·3138 | 1·01247 | ·01231 | ·98769 | 81 |
| 10 | ·17365 | ·82635 | 5·7588 | ·17633 | 5·6713 | 1·01543 | 01519 | 98481 | 80 |
| 11 | ·19081 | ·80919 | 5 2108 | ·19438 | 5·1446 | 1.01872 | ·01837 | ·98163 | 79 |
| 12 | ·20791 | ·79209 | 4·8097 | ·21256 | 4·7046 | 1 02234 | ·02185 | ·97815 | 78 |
| 13 | ·22495 | ·77505 | 4·4454 | 23087 | 4·3315 | 1·02630 | ·02563 | ·97437 | 77 |
| 14 | ·24192 | ·75808 | 4·1336 | ·24933 | 4 0108 | 1·03061 | ·02970 | ·97030 | 76 |
| 15 | ·25882 | ·74118 | 3 8637 | ·26795 | 3·7321 | 1·03528 | ·03407 | ·96593 | 75 |
| 16 | ·27564 | ·72436 | 3·6280 | ·28675 | 3·4874 | 1·04030 | ·03874 | ·96126 | 74 |
| 17 | ·29237 | ·70763 | 3·4203 | ·30573 | 3·2709 | 1·04569 | ·04370 | 95630 | 73 |
| 18 | ·30902 | ·69098 | 3·2361 | ·32492 | 3·0777 | 1 05146 | ·04894 | ·95106 | 72 |
| 19 | ·32557 | ·67443 | 3 0716 | ·34443 | 2 9042 | 1·05762 | ·05448 | ·94552 | 71 |
| 20 | 34202 | ·65798 | 2 9238 | ·36397 | 2·7475 | 1·06418 | ·06031 | ·93969 | 70 |
| 21 | ·35837 | ·64163 | 2·7904 | ·38386 | 2·6051 | 1·07115 | ·06642 | ·93358 | 69 |
| 22 | ·37461 | ·62539 | 2·6695 | ·40403 | 2 4751 | 1 07853 | ·07282 | ·92718 | 68 |
| 23 | ·39073 | ·60927 | 2·5593 | ·42447 | 2·3559 | 1 08636 | ·07950 | 92050 | 67 |
| 24 | ·40674 | ·59326 | 2·4586 | ·44523 | 2·2460 | 1·09464 | ·08645 | ·91355 | 66 |
| 25 | 42262 | ·57738 | 2·3662 | ·46631 | 2·1445 | 1 10338 | ·09369 | ·90631 | 65 |
| 26 | 43837 | ·56163 | 2·2812 | ·48773 | 2·0503 | 1·11260 | ·10121 | ·89879 | 64 |
| 27 | 45399 | ·54601 | 2 2027 | ·50953 | 1·9626 | 1 12233 | ·10899 | ·89101 | 63 |
| 28 | ·46947 | 53053 | 2·1301 | ·53171 | 1.8807 | 1·13257 | ·11705 | ·88295 | 62 |
| 29 | ·48481 | ·51519 | 2·0627 | ·55431 | 1·8040 | 1·14335 | ·12538 | ·87462 | 61 |
| 30 | ·50000 | ·50000 | 2·0000 | ·57735 | 1 7321 | 1 15470 | ·13397 | ·86603 | 60 |
| 31 | ·51504 | ·48496 | 1·9416 | ·60086 | 1·6643 | 1 16663 | ·14283 | ·85717 | 59 |
| 32 | ·52992 | ·47008 | 1 8871 | ·62487 | 1·6003 | 1·17918 | ·15195 | ·84805 | 58 |
| 33 | ·54464 | ·45536 | 1·8361 | ·64941 | 1·5399 | 1·19236 | ·16133 | ·83867 | 57 |
| 34 | ·55919 | ·44081 | 1·7883 | ·67451 | 1·4826 | 1 20622 | ·17096 | ·82904 | 56 |
| 35 | ·57358 | ·42642 | 1·7434 | 70021 | 1·4281 | 1·22077 | ·18085 | ·81915 | 55 |
| 36 | ·58779 | ·41221 | 1·7013 | 72654 | 1·3764 | 1·23607 | ·19098 | ·80902 | 54 |
| 37 | ·60182 | ·39819 | 1 6616 | ·75355 | 1·3270 | 1·25214 | ·20136 | ·79864 | 53 |
| 38 | ·61566 | ·38434 | 1·6243 | ·78129 | 1·2799 | 1·26902 | ·21199 | ·78801 | 52 |
| 39 | ·62932 | ·37068 | 1·5890 | ·80978 | 1·2349 | 1·28676 | ·22285 | ·77715 | 51 |
| 40 | ·64279 | ·35721 | 1·5557 | 83910 | 1·1918 | 1·30541 | ·23396 | ·76604 | 50 |
| 41 | ·65606 | ·34394 | 1·5243 | ·86929 | 1 1504 | 1·32501 | ·24529 | ·75471 | 49 |
| 42 | ·66913 | ·33087 | 1,4945 | 90040 | 1·1106 | 1·34563 | ·25686 | ·74314 | 48 |
| 43 | ·68200 | ·31800 | 1·4663 | ·93252 | 1·0724 | 1 36733 | 26865 | ·73135 | 47 |
| 44 | ·69466 | 30534 | 1·4396 | ·96569 | 1·0355 | 1·39016 | ·28066 | ·71934 | 46 |
| 45 | ·70711 | ·29289 | 1·4142 | 1·00000 | 1·0000 | 1·41421 | ·29289 | ·70711 | 45 |
| | Cosin | Versin | Secant. | Cotan | Tan. | Cosec. | Covn | Sine. | Deg |

## ON THE USE OF THE TABLE OF NATURAL SINES, &c., IN INCLINE MEASURES.

### THE COLUMN OF SINES

Gives the length of the perpendicular side of a right-angled triangle when the hypothenuse or radius is 1 or unity.

To find the height gained on a slope or slant when the length and degree is given :

*Example 1 :* In a breast 400 feet in length, pitching 36°, what is the vertical height gained ? Opposite 36 in column of degrees, find ·58779 as length of sine ; then by proportion, as 1 : ·58779 :: 400 feet : 235·116 feet.

*Example 2 :* If a wagon weighing 4 tons is being hoisted up a slope of 30° what is the strain on the rope, independent of friction and weight of rope ? Opposite 30 in first column, find in column of sines ·5 ; then, as the vertical height is to the length of the slope so is the strain on the rope to the weight ; or, by proportion, as ·5 : 1 :: 2 tons : 4 tons.

Then from a table on strength of ropes we find the required rope for work, due allowance being made for weight of rope, friction, factor of safety, &c. For an angle greater than 45° commence at the bottom of right hand column.

### THE COLUMN OF COSINES.

This column gives the length of the base or horizontal measurement of a right-angled triangle, the hypothenuse being 1 or unity. To obtain the horizontal measurement by proportion when the hypothenuse or incline and angle is given : As 1 : cosine :: length of plane : the base or horizontal measurement.

*Example 1 :* A slope is 870 feet in depth and pitches at 35°, what is the horizontal distance, or how long should it be made upon the map ? Opposite 35°, on the first or degree column, find ·81915 ; then as 1 : ·81915 :: 870 : 712·66 feet.

To find the cubic contents of coal seams. Let T equal thickness of the seam in yards. Then

$$\frac{4840 \times T}{\text{cosine.}} = \text{cubic yards in one acre.}$$

*Example :* How many cubic yards are in a field of 12 acres containing a seam of coal 6 feet thick at a pitch of 30° ? Find in column of cosines opposite 30°, ·86603 ; then, 6 feet are equivalent to 2 yards, which is the thickness of seam, or T. Then

$$\frac{4840 \times 2}{\cdot 86603} = 11177{\cdot}56 \text{ cubic yards,}$$

or the contents per acre, and 11177·56 × 12, the number of acres, = 134,130·72 cubic yards, the contents of the tract.

This table is also used in the solution of problems in connection with right-angled triangles. Let us suppose for instance there is a seam of coal dipping at an angle of 35° westward, and it is desired to sink a shaft 300 feet west of the outcroppings. When the surface is level it is plain that the seam, the line from the outcroppings to the shaft, and the shaft, when sunk, forms a right-angled triangle. The line on the surface can be taken as the cosine while the shaft forms the sine I. C. on diagram, page 33, and the seam forms the radius. Hence, we make the following proportion :

cosine 35° sine 35°
As ·81915 : .57358 :: 300 : 210 feet, the depth of the shaft.

Or the surface line may be taken as the radius, the shaft as the tangent and the seam as the secant. See diagram on page 33. Then as

radius tangent 35°
1 : .70021 :: 300 : 210 feet, the depth of shaft.

Again, let us suppose in a shaft there is a seam 50 feet from the bottom, dipping at an angle of 30° east, it is desired to drive a tunnel from the bottom of the shaft across the measures till it meets the seam. The distance from the bottom of the shaft to the seam can be taken as the sine, the tunnel as the cosine, and the seam as the radius, thus :

sine 30° cos. 30°
As ·5 : ·86603 :: 50 : 86·6 feet, the length of the tunnel.

The table is further used for finding the northing and southing, easting and westing of a survey. Thus, if we desire to know the northing and easting of N. 18° E., 56 links, we find in the table opposite 180, ·95006 cos. and ·30902 sin., which multiplied by 56 gives 53·26 northing and 17·3 of easting, and the distance between the extreme points may be found as follows :

$$\sqrt{53{\cdot}26^2 + 17{\cdot}3^2} = 56 \text{ nearly.}$$

## MENSURATION.

To find the area of a square, rectangle, rhombus or rhomboid, multiply the base by the altitude.

To find the area of a trapezoid multiply one-half the sum of the parallel sides by the altitude.

Circumference of circle = diameter multiplied by 3·1416.

Area of circle = diameter squared × ·7854.

Area of sector of circle = length of arc × ½ radius.

Diameter of circle = circumference ÷ 3·1416.

Surface of cylinder = length × circumference + area of of both ends.

Surface of cone = circumference of base × ½ slant height + area of base.

Surface of sphere = diameter squared × 3·1416.

Area of triangle = base multiplied by ½ the altitude.

Contents of cylinder = area of one end × length.

Contents of sphere = diameter cubed × .5236.

Contents of cone = area of base × ⅓ perpendicular.

# MINE SURVEYING.

## COMPASS SURVEYING.

Surveying with the compass, though less accurate than Vernier surveying, is so much more simple, so easily learned, and so peculiarly adapted for the use of miners and mine bosses, that it will be best to treat of it more in detail than its more complicated substitutes.

The compass best adapted for beginners is one on which the plate is divided into quadrants, that is from 0 to 90°, from 90° to 0, and so on.

After a compass, either a common hand one or one which can be mounted on a tripod for convenience of leveling, has been obtained, it is first placed over that point from which the survey is to be started. It is then leveled to allow the needle to swing easily. When the rod or light is held over the point on which the first sight is to be taken, the direction, after sighting the instrument, may be easily ascertained as soon as the needle has steadied itself, by observing the number of degrees and between what points on the compass the north end of the needle (distinguished by a silver wire found always on the south end) may steady itself. The distance between these two points is then accurately measured, noting any intermediate points which the operator may desire to have.

The instrument is then moved and placed over that point to which the first sight was taken and leveled.

The method pursued in taking the previous sight must then be repeated and so continued till the end of the survey is reached, when the notes are ready to be placed on paper by plotting, which will be treated of hereafter.

To make a survey of this kind is so easily understood, that it would be best for all who have not had the experience, to adopt this plan before they attempt to master the more difficult art of making a Vernier survey.

## VERNIER SURVEYING.

In treating of surveying of this kind it may be said in the start, that the operator who has been making surveys with the compass for some time, is much better able to begin with the Vernier than one who has had no experi-

ence with the needle. To make a Vernier survey a Transit with sliding plate and vertical circle must be had. The sliding plate is arranged under and on the outside edge of the compass box, and is divided into degrees and halves from 0 to 360°, while a small plate, called the Vernier, above the lower, records the minutes. On the Transit the compass plate is generally divided the same as the Vernier plate and not into quadrants. In starting the survey the instrument must first be placed by means of a plummet directly over the point of beginning and leveled. The sliding plate is then set so that it coincides with 0 of the Vernier, and the plate is then clamped and turned so that the north end of the needle corresponds with 0 on the compass plate. The lower screw is then fastened and the Vernier plate screw loosened when the first sight is taken, and the course recorded by noticing beyond what number of degrees on the lower plate the 0 of the Vernier points and the number of minutes beyond this, by counting on the Vernier from 0 to where a line on the Vernier exactly corresponds with one on the lower plate. As a check the needle course is recorded, which should nearly correspond with that of the Vernier, according to the quantity of magnetic attraction by which it may be influenced. The instrument is then moved and set exactly on the point where the sight had just been taken and again leveled, great care being taken to have the same reading on the plate as was recorded at the previous sight. While the plates remain clamped the lower screw is loosened and a sight is taken back upon the point just left. When this is done the order is reversed, the lower screw being fastened and the Vernier plate allowed to move and another sight ahead is taken and the course read. At this point, by referring to the needle, which has been mentioned heretofore to be used as a check, the course will be found to differ from the reading on the Vernier 180°, or as near thereto as the magnetic attraction will permit. The needle being established as the meridian at the beginning of the survey, it will be seen at once that the reading on the Vernier is not correct, but is recording a course directly opposite to the one being run, and in order to overcome this difficulty the true course is recorded by adding or subtracting the difference 180° after taking into consideration the direction of the survey. The instrument is then moved to the next station and the same course pursued and so continued through-

out the whole of the survey, great care being constantly taken by using the needle as a check to avoid noting courses in opposite directions to the correct ones, and to bear in mind to note the distance between all stations and intermediate points.

The vertical circle is divided from 0 to 90° to the right and left of the centre, and has a Vernier attached in order that slopes may be minutely recorded, taken either up or down. In taking an angle the sight must be taken in the rod or light at the same distance from the ground as is the telescope of the instrument. The angle is then recorded from the circle in the same manner as one from the Vernier plate, and is marked plus or minus, according as the sight is taken up or down.

The distance between the points having been ascertained, the vertical height may be found by means of tables provided for that purpose.

## PLOTTING.

The survey having been made, it is easy to draw a plan of it on paper, For this purpose draw a straight line to represent the meridian passing through the first station. An angle is then laid off equal to the angle which the first sight of the survey makes with the meridian and the length of the sight and the intermediate points marked off from a scale of equal parts. Through the extremity of this course a second meridian parallel to the first can be drawn and the same course pursued as before. By this means the entire survey can be plotted, but in order to avoid the inconvenience of drawing a meridian through every station, an instrument called the ⋄ square can be used by placing the blade parallel to the meridian, and sliding it along the table from station to station with the protractor, from which the angles are laid off, held closely against it.

## LEVELING.

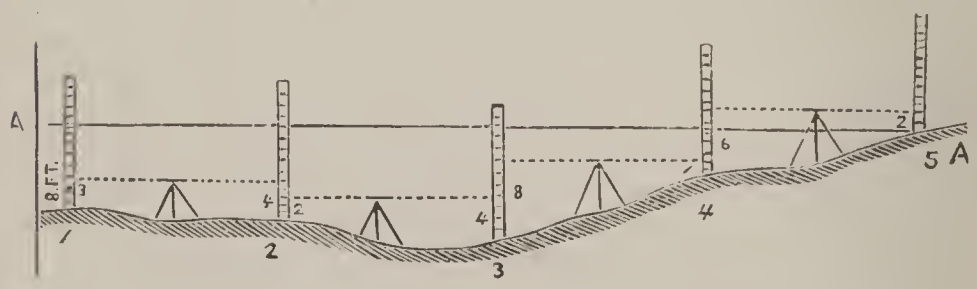
In leveling there is little to be remembered and little more required than common care, as it is simply the art of determining the difference of level between any two points.

The leveling instrument generally consists of a large spirit-level attached to a telescope and mounted on a

tripod similar to a Transit. The surveyor should also be provided with a leveling staff, which consists of a straight bar of wood, six feet or more in length, divided into inches and tenths of an inch, and having a groove running its entire length. A smaller staff of the same length called the slide, also divided into inches and tenths, is inserted in this groove and moves freely along it. At the upper end of the slide is a rectangular or round piece of metal called a target, about six inches wide, divided into four equal parts by two lines drawn at right angles to each other, with the opposite parts painted different, so that they may be distinguished at great distances.

Having adjusted the level by means of the proper screws, turn the telescope to the staff held in the rear, and note the height on it to which the target is raised in order to correspond with the wires of the telescope. The instrument is then placed beyond the staff and a back sight taken on the staff. Level in the same manner from station to station until the desired point be reached, when the difference of level between the first and last stations may be readily found by taking the difference between the sum of the heights at the back and the forward stations.

This is very simple, easily understood and quickly learned, as can be seen by the following sketch :




Placing the instrument at a point advantageous for a sight both back and forward the heights are read from the rod and recorded under Back Sights and Fore Sights, as follows :

| Sta. | B. S. | F. S. |
|---|---|---|
| 1 | 3 | |
| 2 | 2 | 4 |
| 3 | 8 | 4 |
| 4 | 6 | 1 |
| 5 | | 2 |
| | 19 | 11 |

As the Back Sights in this case exceed the Fore Sights by 8 the last Sta. 5 is 8 feet higher than Sta. 1, indicated by the black line AA.

The levels can be carried this way an indefinite distance, in any direction, and so long as the Back Sights are in excess you are running up hill, and when the Fore Sights are the greater, you are descending.

---

## HOW TO USE THE GRADOMETER, OR GRADING LEVEL.

This instrument is of great utility in finding the pitch or angle of slopes, roads, chutes, pipes, &c., and for making profiles of breasts or workings, to find the perpendicular height attained when approaching old levels or workings full of water or gas.

To find the angle of dip, place the blade in the groove of the leg containing the spirit level ; place the other leg upon the surface or plane of which you wish to ascertain the pitch or angle ; open until the spirit-level shows the bubble in the centre of the glass ; the angle up to 45° will be found on the blade.

To find the angle of dip when it is over 45°, open the blade until it makes a right angle with the leg ; place on the surface or plane, and fold in the leg containing the spirit level until the bubble shows in the centre of the glass ; push the blade into the groove, taking care not to move the legs, and the degrees indicated taken from 90° will be the angle of dip required.

---

## TO ASCERTAIN THE SCALE OF A PLAN OR MAP, WHEN IT IS NOT STATED.

When the area of any portion is known, the scale may be found by measuring that portion by any scale. Then use the following formula :—

$a$=area as given on the plan.
$s$=assumed scale.
$x$=correct scale.
$m$=area by assumed scale, then

$$\sqrt{\frac{s^2 \times a}{m}} = x \text{ or, } x^2 = \frac{s^2 \times a}{m}$$

## USEFUL NUMBERS IN SURVEYING.

| For converting | | | Multiplier. | Converse. |
|---|---|---|---|---|
| Feet | into | links..... | 1·515 | .66 |
| Yards | " | links..... | 4·545 | .22 |
| Sq. feet | " | acres..... | .0000229 | 43,560· |
| Sq. yards | " | acres..... | .0002066 | 4,840· |
| Feet | " | miles..... | .00019 | 5,280· |
| Yards | " | miles..... | .00057 | 1,760· |
| Chains | " | miles..... | .0125 | 80· |

## CHAINING ON SLOPES.

A=Angle of slope.
L=Length of line chained on slope.
l=Length of line reduced to horizontal.
l=LK. K=cos. A.
(See table of Natural Sines and Tangents.)

## TO SET OUT A RIGHT ANGLE WITH A CHAIN.

Take 40 links on the chain, 30 links for the perpendicular and 50 for the hypothenuse.

## COMPUTATION OF ACREAGE.

Divide the area into convenient triangles, and multiply the base of each triangle in links by half the perpendicular in links; cut off five figures to the *right*, the remaining figures will be acres; multiply the five figures so cut off by 4. and again cut off five figures, and the remainder is in roods; multiply the five figures by 40, and again cut off for perches.

# NOTES ON MINING.

## PROSPECTING.

For prospecting mineral land diamond-pointed drilling machines have superseded all other systems, and results wholly unattainable otherwise are accomplished. In hard or soft measures cores for the whole distance bored, whether perpendicular or horizontal, are secured. These are in the form of solid cylinders, showing clearly the stratification and mineral passed through, the size and quality of the veins, &c., thus furnishing valuable information in making contracts for shafting or tunneling. The samples of mineral secured are not pieces of disintegrated vein matter, but perfect sections of the ore body or seam, which can be labeled and preserved for future reference.

The average progress made in prospecting in the Anthracite coal region is from 50 to 100 feet per week, including all delays due to drawing core from holes, &c. In the bituminous region the average progress made is from 75 to 125 feet per week. Holes have been put down 2100 feet, the original size of hole being preserved to the bottom, and it is claimed that the limit of depth that can be reached has not as yet been found.

## SHAFTING AND TUNNELING.

Power drills driven by steam or compressed air are superseding hand-drilling in rock work. Much more rapid progress can be made with them and at less cost.

Compressed air is the preferable motor, as it can be carried for great distances without any considerable loss of power, and in many localities it is difficult to get rid of the exhaust steam. Then the working of the drill with compressed air affords a supply of pure fresh air that is frequently a very important desideratum.

Steel-pointed rock drills are operated upon the "percussion" or "blow" principle, while the diamond-pointed

drills are borers. With the diamond drills sinking by the long hole process has been very successfully conducted in the Anthracite region. At the East Norwegian shafts, near Pottsville, which are down 1600 feet, the best drilling was 79 feet in 12 hours, and the best blasting 80 feet per month.

The steel-pointed or "percussion" drills are extensively used in sinking, driving and all kinds of drilling in mines, and for quarry and railroad work. For surface work they are mounted on tripods, for shafting or tunneling on bars or columns securely fastened against the sides or top and bottom of the work, or are mounted on wagons adapted for the purpose.

The cost of shafting and tunneling, of course, varies with the strata. A shaft through conglomerate, such as overlies the Mammoth vein in the Anthracite region, 15 by 25 feet in area, all hand drilling, will cost about $2 00 per yard. Through the same strata, a tunnel 8 by 9 feet can be driven, with the use of the present explosives, for $50 per yard. Slopes timbered with bottom and top sills 20 feet long, legs 14 feet high, and with timber 5 feet from centre to centre, can be sunk in the Anthracite region, if there is not too much water, for about $40 per yard.

In sinking, first mark off the ground and then dig out the soil to a depth of six feet. Put in a crib of timber at the bottom of the pit thus formed, and another three feet above this, supported on props, and a third and fourth, so that the top crib is 3 feet above the surface for tipping rubbish. Back up the cribs with plank, and proceed similarly for the next six feet, and so on until the solid is reached, when the sides will stand without temporary support.

---

## HAULAGE.

There has been but little experience in this country with the various systems of haulage, such as tail rope, endless chain, &c., that are employed in Europe to cheapen the cost of the inside movement of coal. They have been introduced at some places, however, and may come into more general use in the future.

For cars underground with 11½ inch wheels, the friction to be overcome may be taken at $\frac{1}{100}$ of the load, when the

road is in first-rate condition. When the road is in ordinary condition, at $\frac{1}{70}$ of the load.

The friction of the ropes and sheaves may be taken at $\frac{1}{33}$ of their weight; the sheaves are, as a rule, 30 lb. in weight and 10 yards apart.

The least practical gradient for a self-acting incline is 1 in 30; and the angle of equal resistance of fulls and empties in both directions is 1 in 111.

The following is the formula to find the inclination of the road to make the resistance equal in both directions:

Let W = weight of a loaded wagon or tub.
$w$ = " " an empty wagon or tub.
F = measure of friction.
X = inclination required.

$$\text{Then } X = \frac{W - w}{W + w} \times F$$

The following is the formula for finding the least inclination at which the full set will hold the empty one in suspension:

$$X = \frac{W + w}{W - w} \times F$$

The useful effect of a hauling engine in coal conveyed may be taken at 50 per cent. of the steam pressure.

Mr. T. F. Thomas, of England, in his "Notes on Coal Mining," lays down the following general rules with respect to the different methods of underground haulage.

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## TAIL ROPE SYSTEM.

This system of hauling may be used under almost any circumstances, and is to be recommended particularly in the following cases:

When the gradient dipping inbye is not sufficient for the empties to drag the rope after them.

When the gradient outbye is not sufficient for the sets to self-act.

When the full wagon or tubs coming outbye will not pull the ropes after them.

## ENDLESS CHAIN SYSTEM.

This system is particularly applicable to the following cases :

When the two ends of the engine plane are about on the same level.

When the gradient is heavy.

When the road is straight.

The advantages of this system are that a low speed is required, varying from 1 to 3 miles per hour ; consequently, a very good road is not needed, and a small engine is sufficient.

---

## ENDLESS ROPE SYSTEM No. 1.

A double road is necessary. 12 to 30 tubs are run in a set.

The advantages are :

A driving-wheel used instead of a drum.

One-third less rope used than in the Main and Tail Rope system.

No power is lost in brakeing the drum.

It is, however, difficult to apply this system where there are many branches, because of the tightness of the rope.

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## ENDLESS ROPE SYSTEM NO 2.

This system is applicable only where the road has no branches and has a rise in one direction, but it may have any curves.

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## MINE LOCOMOTIVES.

The mine locomotives lately introduced are much more economical than mule power, and, if it were not for the deleterious gases they generate, would be used wherever the sizes of the openings would permit and the length of the hauls make them advantageous.

Mr. T. D. Jones, now Superintendent of the Ebervale Coal Company, in his last report as Inspector of the Southern District of Luzerne and Carbon counties, says of the use of the mine locomotive that the following conditions should be taken into consideration :

Adequate ventilation produced by mechanical appliances; that by fan preferable. Velocity of the air current should be from 8 to 12 feet per second. The mean speed of the locomotive is about 7 feet a second, which is a trifle less than the velocity of the air current suggested. The size of gangways and tunnels, where locomotive travels, should not be less than 7 feet high by 10 feet wide ; the more room the better. The locomotive track should be kept in good condition.

The engine run should be from tunnel mouth, bottom of shaft, or foot of slope, as the case may be, to inside tunnel or siding ; men ought not to be permitted to work on the route of the locomotive, owing to the noxious gases emitted.

The result of an investigation into the comparative cost of haulage by mine locomotives and mules in Mr. Jones' district, at nineteen collieries, showed a saving of more than one-half by locomotive haulage.

Men should not be compelled to work in air fouled by mine locomotives, as carbonic oxide is produced by them. It is very destructive to animal life, and very serious accidents have already been traced to it where it has been generated in this way.

## WORKING OF BITUMINOUS SEAMS.

All coal seams are worked by one of the two methods' Longwall, or Pillar and Stall, or by some modification of one of these two methods.

The Longwall method can be adopted with advantage when the seam is small, free from faults, and has a good roof.

The Pillar and Stall method is best when the roof is wet, the coal full of gas, or it is desired to prevent sinking of the surface.

In Longwall it is estimated that about 15 per cent. more large coal is obtained than in Pillar and Stall, and from 10 to 25 per cent. more coal per acre.

The following are general directions for working in the different methods :

## LONGWALL.

In soft seams, when the roof crushes, the wall-face should be perpendicular to the cleat, and in strong seams parallel to the cleat. Its proper position is more dependent upon the inclination of the seam than upon the direction of the cleat, and the following general rules should be observed :

If the inclination of the seam is moderate, the wall-face should be perpendicular to the dip, when the roads will be easy to maintain, and a level course is obtained in the face.

Where the dip of the seam is considerable, the wall-face should be parallel to the direction of dip, when the principal roads for bringing down the coal will be cross-cuts, which can be worked likely as self-acting inclines. The stalls will be very short, not more than 5 yards long each. This method prevents accumulation of gas in the face, which would result if the wall-face were perpendicular to the rise of the seam.

---

## PILLAR AND STALL.

The size of the pillars will depend on the depth of the seam from the surface.

In his "Winning and Working of Collieries," Mr. Dunn, of England, gives the following scale for first working, with the design of afterwards taking out the pillars, the width of the principal workings being 5 yards, and cross holings 2 yards.

| Depth in feet. | Size of pillars in yards. | Proportion in pillars. | Depth in feet. | Size of pillars in yards. | Proportion in pillars. |
|---|---|---|---|---|---|
| 120 | 20 by 5 | ·41 | 1080 | 26 by 14 | ·69 |
| 240 | 20 " 6 | ·50 | 1200 | 26 " 16 | ·71 |
| 360 | 22 " 7 | ·52 | 1320 | 18 " 18 | ·73 |
| 480 | 22 " 8 | ·57 | 1440 | 28 " 20 | ·75 |
| 600 | 22 " 9 | ·59 | 1560 | 30 " 21 | ·77 |
| 720 | 22 " 12 | ·61 | 1680 | 30 " 22½ | ·78 |
| 840 | 26 " 15 | ·63 | 1800 | 30 " 24 | ·79 |
| 960 | 28 " 16 | ·66 | M. Wear-mouth, | 40 " 29 | ·80 |

## PROPORTION OF PILLARS TO OPENINGS.

In the following table, the weight thrown upon pillars at different depths by the removal of different proportions of coal is given.

| Depth of seam in feet. | Weight on Pillars, the proportion to mine got being 90 per cent. Lbs. per sq. in. | 80 per cent. Lbs. per sq. in | 70 per cent. Lbs. per sq. in. | 60 per cent. Lbs. per sq. in. | 50 per cent. Lbs per sq. in. | 40 per cent. Lbs. per sq. in. | 30 per cent. Lbs. per sq. in. | 20 per cent. Lbs. per sq. in. | 10 per cent. Lbs. per sq. in. |
|---|---|---|---|---|---|---|---|---|---|
| 100 | 111 | 125 | 142 | 165 | 200 | 250 | 333 | 500 | 1,000 |
| 500 | 555 | 625 | 710 | 830 | 1,000 | 1,250 | 1,665 | 2,500 | 5,000 |
| 1,000 | 1,111 | 1,250 | 1,428 | 1,666 | 2,000 | 2,500 | 3,333 | 5,000 | 10,000 |
| 1,500 | 1,666 | 1,875 | 2,138 | 2,496 | 3,000 | 3,750 | 4,998 | 7,500 | 15,000 |
| 2,000 | 2,222 | 2,500 | 2,956 | 3,333 | 4,000 | 5,000 | 6,666 | ..... | ..... |
| 3,000 | 3,333 | 3,750 | 4,284 | 4,999 | 6,000 | 7,500 | ..... | ..... | ..... |
| 4,000 | 4,444 | 5,000 | 5,912 | 6,666 | 8,000 | ..... | ..... | ..... | ..... |
| 5,000 | 5,555 | 6,250 | 7,340 | ..... | ..... | ..... | ..... | ..... | ..... |
| 10,000 | 11,111 | 12,500 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

## WORKING OF ANTHRACITE SEAMS.

### HINTS FOR THE MAMMOTH SEAM WHEN IT IS SOFT AND SHELLY OR SLIPPERY, AT AN ANGLE OF MORE THAN 50°, AND GENERATING LARGE QUANTITIES OF FIRE-DAMP.

The great danger to be guarded against is the sudden liberation of gas should a breast "run;" that is, should the coal at the face loosen and run out of its own gravity, only stopping when it chokes or fills up the open space below. To meet these conditions, the air-course may be driven above the gangway and used as a return, the fan being attached as an exhaust, and the working breasts ventilated in pairs. The inside manway of one of a pair of breasts is connected with the gangway for the intake and the outside manway of the other breast with the return air-way, giving each pair of breasts a separate split of the current. In collieries where this system of working is followed the coal is soft. A new breast is worked up a few yards, but as soon as it is opened out the coal runs freely and the manways are pushed up on each side as rapidly as possible, to keep up with the face. The two miners, one on

either side, sometimes finish a breast without being able to cross to each other. The work is done exclusively with Davy lamps, and when a breast "runs" the gas is liberated in such quantities that it frequently fills breasts from the top to the air-way before the men can get down the manway on the return side. When the gas reaches the cross-hole, it passes into the return air-way without reaching any part where men are working. Should a "run" of coal block a breast by closing the manway, it affects the current of one pair of breasts alone. As the gangway is the intake, leakage at the batteries passes into the breasts, as the cross-holes are above their level and the gas is thus kept above the starter when at the draw-hole. The gangway, chutes and air-way are supplied by wooden pipes, which connect with a door behind the inside chute. If a breast runs up to the surface, it does not affect the return air-way, as it is in the solid.

Among the disadvantages urged against this system of working are the following :

It increases the friction, as the air must pass in the air-way all the distance from the breast to the fan, the area of the air-way being small in comparison to the gangway or intake.

As the faces of the breasts are so much higher than the return air-way, the lighter gas must be forced down into the return against the buoyant power of its smaller specific gravity.

The reduction of friction obtained by splitting is neutralized by each split running up one small manway and down another ; the advantage of running through several pillar headings and thus securing a shorter course being lost. This can be partly obviated by ventilating the breasts in groups, but the dangers avoided in splitting are increased.

Black-damp, which accumulates in the empty or partly empty breasts, works its way down and mixes with the intake current, as there is no return current in the breast strong enough to carry it away, the return being closed in the air-way.

All things considered, when the seam is soft and has a pitch of 40° and upward, and emits large quantities of gas in sudden outbursts, as in running breasts, this system is the best that can be adopted.

WHEN THE COAL IS HARD AND GAS IS NOT FREELY EVOLVED.

The reverse of the system just described is followed at some collieries where the coal is hard and but little gas is encountered. The air-way is driven over the gangway or against the top, the fan being used to force the air inward to the end of the air-way. The air is distributed as it returns, being held up at intervals by distributing doors placed along the gangway.

Among the advantages claimed for this plan are the following :

As the pressure is outward, it forces smoke and gas out at any openings which may exist from crop-hole falls or other causes.

The warm air from the interior of the mine returning up the hoisting slope or shaft prevents it from freezing.

As the current is carried from the fan to the end of each lift without passing through working places, the opening of doors as cars are passing, &c., does not interfere with the current.

If a locomotive is used, the smoke and gases generated by it are carried away from the men toward the bottom. Locomotives are generally used only from the main turnout to the bottom.

An objection to this system is that the gangway, as the return, is apt to be smoky. Starters and loaders are forced to work in more or less smoke, and even the mules work to disadvantage, while if gas is given off, it is passed out over the lights of those working in the gangway.

However, in places where there is but little gas and airways of large area can be driven, this plan works very satisfactorily, and some of the best ventilated collieries are worked upon it.

An objection advanced by some against forcing-fans, is that they increase the pressure, thus damming the gas back in the strata. In case the speed of the fan is slacked off, the accumulated gas may respond to the lessened pressure and spring out in large volumes from its pent-up state. This argument, however, works both ways. An exhaust fan, running at a given speed, is taking off pressure, and if anything occurs to block the intake the pressure is diminished, and the gas responds to the decrease upon exactly the same principle.

HINTS FOR THE SMALLER SEAMS WHEN THEY ARE SMALL AND LAY FROM HORIZONTAL TO ABOUT 10°.

Two gangways may be driven, the lower or main gangway being the intake. Branch gangways should then be driven diagonally or at a slant, with a panel or group of working places on each slant gangway. Large headings should connect the panels. In this system the air is carried directly to the face of the gangway and up into the breasts, returning back through the working places. The intake and return are separated by a solid pillar, the only openings being the slant gangways on which are the panels.

The advantages of this plan are several :

The main gangway is solid, with the exception of the small cross-holes connecting with the gangway above ; these furnish air to the gangway and are small and easily kept tight. These stoppings should be built of brick, and made strong enough to withstand concussion.

A full trip of wagons can be loaded and coupled in each panel or section without interfering with or detaining the traffic on the main road ; one trip can be loaded while another is run out to the main gangway for transportation to the bottom.

The only break in the intake current is when a trip of cars is taken out from or returns to a panel or section ; this can be partially provided against by double doors, set far enough apart to permit one to close after the trip before the other is opened. This distance can be secured by opening the first three breasts on a back-switch above the road through the gangway pillar, or by running each branch over the other far enough to obtain the distance for the double doors.

If it is not desired to carry the whole volume of air to the end of the air-way, a split can be made at each branch road. These will act as unequal splits in reducing friction, and although not theoretically correct, are preferable to dragging the whole current the full length of the workings.

The objections urged to this plan are :

That it involves too much expense in the large amount of narrow work at high prices necessary to open out a colliery ; that it necessitates a double track the whole length of the lift, and that the grade ascends into each

panel or section. But the latter criticism falls, because the loss of power hauling the empty wagons up a slight grade is more than made up by the loaded wagons running down, while the mules are away putting a trip into another panel or section.

For a large colliery this is, without doubt, the best and cheapest system.

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### WHEN THE SEAM IS SMALL AND LIES AT AN ANGLE OF MORE THAN 10°.

In small seams lying at an angle of more than 10°, and too small to permit an air-way over the chutes, it is more difficult to maintain ventilation. If air-holes are put through every few breasts, and a fresh start obtained by closing the back holes, or if an opening can be gotten through to the last lift as often as the current becomes weak, an adequate amount of air can be maintained, because the lift worked can be used as the intake and the abandoned lift above as the return. To ventilate fresh ground, the filling of the chutes with coal will have to be depended upon, or a brattice must be carried along the gangway. This can be done for a limited distance only, as brattice leaks too much air. As a rule, collieries worked upon this plan are run along until the smoke accumulates and the ventilation becomes poor ; then a new hole is run through and the brattice removed and used as before for the next section. This operation is repeated until the lift is worked out. Sometimes, to make the chutes tight, canvas covers are put on the drawholes, but, as they are usually left to the loaders to adjust, they are often very imperfectly applied. Then, as the coal is frequently very large, the air will leak through the batteries.

This plan works very satisfactorily if the openings are made at short intervals, say as frequent as every fifth breast, but the distance is usually much greater to save expense. As the power of the current decreases as the distance between the air-holes is increased, good ventilation is entirely a question of how often a cut-off is obtained.

An effective ventilation could be maintained in a small seam at a heavy angle by working with short lifts, say two

lifts of fifty yards instead of one of a hundred as at present. The gangways should be frequently connected, and one used as an intake and the other as a return. This would necessitate driving two gangways where one is now made to do, but the additional expense would be made up in the greater proportion of coal won.

## PRODUCE OF COAL SEAMS.

### SPECIFIC GRAVITY AND WEIGHT OF COAL.

To determine the specific gravity of coal, take a small piece of coal, suspend it by means of a horse hair from the under side of the pan of a carefully adjusted balance, and weigh it both in and out of water ; divide its weight in the air *by the loss of weight* in the water, and the quotient is the specific gravity.

*Example :*

A piece of coal weighs say 480 grains.

Loss of weight when weighed in water, 398 grains.

Then $\frac{480}{398}$=1·206, specific gravity of the coal compared with water at 1·000.

The following table gives the weight and specific gravity of various coals :

| Name of Coal. | S. G. | Weight of a cubic foot in lbs. | Weight of a cubic yard in tons. |
|---|---|---|---|
| Newcastle Hartley, Eng.... | 1·29 | 80·6 | ·972 |
| Wigan, 4 feet, Eng..... | 1·2 | 75· | ·9[illegible]4 |
| Portland, Eng..... | 1·30 | 81·2 | ·978 |
| Anthracite, Wales..... | 1·39 | 86·9 | 1·047 |
| Eglington, Scotland..... | 1·25 | 78·1 | ·941 |
| Anthracite, Irish..... | 1·59 | 99·4 | 1·193 |
| Anthracite, Penn..... | 1·55 | 96·9 | 1·167 |
| Bituminous, " ..... | 1·40 | 87·5 | 1·054 |
| Block Coal, Ind..... | 1·27 | 79·4 | ·956 |

## PRODUCE OF BITUMINOUS SEAMS.

A ready way of finding the quantity of available coal in a given area of a seam is given by W. Fairley, M. E., of England. He takes an acre of coal one inch thick to contain 100 tons. This leaves a sufficient margin for faults and loss of working. Thus: a vein of coal twenty-four inches thick will yield 24 00 tons per acre.

To ascertain the exact quantity of coal under a given area—presuming the seam to be of regular thickness and quality throughout—find the specific gravity; then, as this represents the weight of a cubic foot in ounces, it is simply a matter of calculation to obtain the gross weight.

The exact weight of coal seams can be got from the table below:

| Specific gravity | Weight in the natural bed, per acre, per inch thick, in tons. | Weight of a cubic foot in the broken state in lbs. | |
|---|---|---|---|
| | | Large coal. | Small coal. |
| 1·10 | 111·411 | 42·62 | 37·12 |
| 1·15 | 116·475 | 44·56 | 38·81 |
| 1·20 | 121·540 | 46·50 | 40·50 |
| 1·25 | 126·604 | 48·43 | 42·18 |
| 1·30 | 131·668 | 50·37 | 43·87 |
| 1·35 | 136·732 | 52·31 | 45·56 |
| 1·40 | 141·796 | 54·25 | 47·25 |
| 1·45 | 146·860 | 56·18 | 48·93 |
| 1·50 | 151·925 | 58·12 | 50·62 |

The weight of coal in its broken state, that is, as it comes to the surface in cars or otherwise, will depend on its mechanical structure; it has been ascertained by experiment with bituminous coal in England that as brought to the surface it weighs, if large, in proportion to the solid coal as 62 is to 100, and the weight of the small as 54 is to 100.

If, then, the figures in the second column be multiplied by the number of inches any bituminous coal seam is in thickness, the result will be the contents per acre in tons.

SHOWING THE NUMBER OF TONS OF COAL UNDER A SQUARE MILE AT DIFFERENT THICKNESSES.

| Feet. | Tons. | Feet. | Tons. |
|---|---|---|---|
| 1 | 972.320 | 9 | 8.750.880 |
| 2 | 1.944.640 | 10 | 9.723.200 |
| 3 | 2.916,960 | 20 | 19.446.400 |
| 4 | 3.889,280 | 30 | 29.169.600 |
| 5 | 4,861,600 | 40 | 38.892.800 |
| 6 | 5.833.920 | 50 | 48.616.000 |
| 7 | 6,806.240 | 60 | 58.339,200 |
| 8 | 7,778,560 | 70 | 68.062,400 |

PRODUCE OF ANTHRACITE COAL SEAMS.

In making calculations upon the net product—or amount of prepared coal that can be shipped from a given area of an anthracite coal seam—allowance must be made for the loss in mining and in preparation. This allowance will vary with the seam, and will be far larger in the Mammoth seam than in those which are not so thick. The result of experience in the anthracite region appears to be that the larger the seam the smaller, proportionally, is the amount of coal saved. Samuel Gay, Esq., Mine Inspector for the Pottsville District, in his report for 1879, makes calculations upon two collieries located in the eastern portion of the Mahanoy District. In each case he estimated the thickness of the seam at 35 feet and allowed 28·5 per cent. for slate, refuse, &c. He estimates the loss in breaking down or preparation at 15 per cent. In the case of the Stanton colliery he found that but 691,297 tons had been saved, while 3,292,7[illegible]3 tons had been lost. At the Gilberton colliery, 3,8[illegible]8,244 tons had been lost in mining and preparation, while the net product was but 1,244,796 tons. No reliable figures to represent the percentage that should be allowed for loss in mining and preparation can be given, as they will vary with every seam and with the topographical character of each lease.

Mr. Joseph S. Harris, Superintendent of the Central Railroad of New Jersey, in his report to the Receivers of the Philadelphia & Reading Coal & Iron Company upon the value of their lands, estimates that 27 per cent. of the contents of all the seams on the company's estate is all that can be shipped.

Hon. Eckley B. Coxe, of Drifton, Luzerne County, says, in the report on "Waste in Mining Anthracite," issued under the auspices of the Geological Survey of Pennsyl-

vania, in reference to the net product from a tract of a little less than 200 acres mined by his firm, the seam not being over 10 feet thick.

The seam is not all worked out in the 200 acres, but there are many breasts unfinished, and some parts unopened ; and there is much coal to be robbed. The average yield is at least 10,000 tons per acre—or 1 ton at least for 43½ cubic feet."

Colonel D. P. Brown says of the product from the Mammoth seam at Lost Creek, where it is 38 feet thick, that it will yield "about 50 per cent. of the seam mined, when the whole section of seam is hauled out. If, however, only the bottom member of the seam is worked, the yield will be about 60 per cent. of the output. When the whole seam is wrought the proportion of coal to refuse is as 65 to 35 ; of the 65 of coal about one-fifth or 20 per cent. will make furnace coal, and 80 per cent. less a breaker waste of 15¼ per cent. will make prepared sizes."

Mr. Chester, the General Superintendent of the Lykens Valley Company, says concerning their mine waste :

"While we have some seams from 8 to 10 feet thick, where the amount left in as loss does not exceed 12 per cent., again we have some seams from 6 to 8 feet thick, with from 5 to 10 feet of slate between two seams of coal, when the loss in mining is from 25 to 30 per cent., and at times the loss is even greater than this where the slate between the seams is very loose and the top to the upper seam is also poor. The least waste in the mine is in the Lykens Valley seam, or in those lying above it and below the Mammoth seam, and the next in loss is the twin seams in the Shamokin region."

Mr. Pratt, of the Geological Survey, thus summarizes the data collected on "Breaker Waste :"

The breaking and screening by hand in the old-fashed way lost 6·28 per cent.; by the present breaker and screens. 15·27 per cent.; so that the breaker is to be held chargeable with extra loss over the old style of 9 per cent.

With reference to waste in the preparation of Anthracite coal, Mr. Joseph S. Harris, who has made experiments with the "old style" rollers, or those with cast-iron teeth, and the "new style" or those with movable steel teeth inserted in a cast-iron body, says, with the "new style" there is a direct saving of from 3 to 5½ per cent. in breaker waste, bringing down the percentage in preparing the product of the Baltimore seam to an average of 12 per cent.

# VENTILATION.

## ATMOSPHERIC AIR.

Atmospheric air is composed of nitrogen gas $\frac{4}{5}$ (nearly), oxygen $\frac{1}{5}$, and carbonic acid gas $\frac{1}{2000}$, combined mechanically, not chemically.

It has weight, which varies as its density varies, which changes with the pressure and the temperature, as indicated by the barometer and thermometer.

It expands, like all bodies, by contact with heat, a rise of temperature increasing its volume. Thus, a bladder filled with air bursts if heated, and a draught is produced in a furnace or stove by lessening the weight of the air which ascends through the pipe or chimney. The rate at which the air expands, under a constant pressure, has been found by experiment to be $\frac{1}{459}$ of its volume for every degree of heat added ; that is, 459 cubic feet of air, under steady pressure, becomes 460 feet by being made one degree warmer.

Having weight it also has pressure, and the space it occupies at any particular point is proportional to that pressure. This is shown by the barometer and by the working of suction and forcing pumps, in which the mercury is forced by the pressure of the air 29½ inches up a glass tube, and the water is forced up a pipe to a height of about 32 or 33 feet. If the tube containing the mercury is an inch square, the 29½ inches will weigh 14·47 pounds, which is the pressure per square inch exerted by the atmosphere upon the surface of all matter at that level. As the ocean of air that surrounds the earth is elastic, the density is greatest at the sea level, which is taken as the base in calculations. In ascending a mountain the density becomes less, because there is less air above to press or force. In going down a shaft below the sea level, the density increases, because the height of the column of air above is increased. For every degree which the barometer falls, the pressure per square foot is lessened more than 70 pounds. This will more clearly appear from the following table, which has been computed by the rule :

Height of barometer in inches $\times$ ·4908 (the weight of a cubic inch of mercury) = pressure per square inch in pounds.

## TABLE OF THE PRESSURE OF AIR AT DIFFERENT HEIGHTS OF THE BAROMETER.

| Height of barometer, in inches. | Pressure per sq. in. in pounds. | Pressure per sq. ft. in pounds. |
|---|---|---|
| 27·0 | 13·25 | 1908·23 |
| 27·25 | 13·37 | 1925·89 |
| 27·5 | 13·49 | 1943·56 |
| 27·75 | 13·61 | 1961·23 |
| 28·0 | 13·74 | 1978·90 |
| 28·25 | 13·86 | 1996·56 |
| 28·5 | 13·98 | 2014·24 |
| 28·75 | 14·11 | 2031·91 |
| 29·0 | 14·23 | 2049·58 |
| 29·25 | 14·35 | 2067·24 |
| 29·5 | 14·47 | 2084·91 |
| 29·75 | 14·60 | 2102·58 |
| 30·0 | 14·72 | 2120·25 |
| 30·25 | 14·84 | 2137·92 |
| 30·5 | 14·96 | 2155·59 |
| 30·75 | 15·09 | 2173·26 |
| 31·0 | 15·21 | 2190·93 |

The mercury falls about one-tenth of an inch for every 90 feet of elevation gained, and the approximate height of mountains and depth of shafts may therefore be found without actual measurement.

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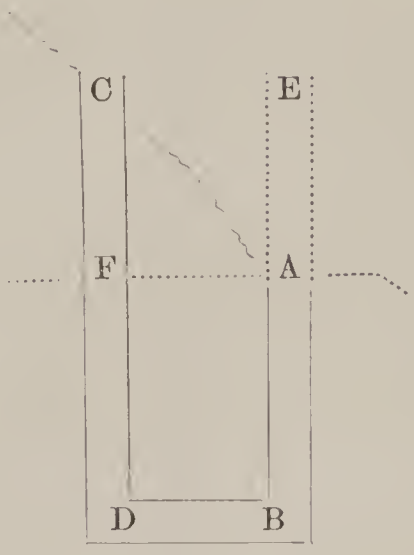
## NATURAL VENTILATION.

In order to understand the theory of natural ventilation, it must be remembered that the height of the atmosphere does not follow the undulations of the earth's surface, but that its outer edge is everywhere equi-distant from the earth's centre, and that if it is 50 miles high from the bottom of a valley it will only be 47 miles high from the summit of a neighboring mountain which is 3 miles high ; from which it follows that the pressure at the summit of the mountain is always less than it is at the bottom of the valley. Hence, if two shafts are sunk from different surface levels to the same level of a seam and are connected by an air-way, and there is a difference in the temperature of the air inside and outside of the mine, there

will be a current of air created, because the density of the columns of air in the two shafts will differ.




To illustrate this, let A B be a shaft 100 feet deep and C D another shaft 200 feet deep, connected at the bottom by the heading B D. Suppose the air inside to be the warmest, as in winter, and for example let the air inside weigh one-half ounce per foot of shaft per square yard of section, and the outside air weigh three-fourths of an ounce for the same bulk; then the relation between the two shafts would stand thus:

| | |
|---|---|
| Shallow shaft, 100 feet at one-half ounce per foot | 50 oz. |
| Outside column from A to E at three-fourths ounce per foot and 100 feet equal | 75 oz. |
| Total | 125 oz. |
| Deep shaft, 200 feet at one-half ounce per foot | 100 " |
| Difference | 25 oz. |

The balance in favor of the shallow shaft, 25 ounces, will make the shallow shaft the downcast by a pressure equal to 25 ounces per square yard of section. If the temperature outside were the highest as in summer, this result would be reversed. The difference of weight between the air in the deeper shaft from F to C and the imaginary column A E is the pressure producing ventilation.

In the case of a drift driven into the side of a hill with an air shaft opened to its summit under similar conditions, the same results are produced. The difference in the weight of the air in the shaft and of an imaginary column in the open air, from the mouth of the drift to the level of the top of the shaft, is the pressure producing ventilation. In winter, when the temperature inside the drift is warmer than the air outside, the current will be up the shaft, but in summer, when the outer air is the warmer, the current will be reversed, and the direction will be out the drift. When the temperatures inside and outside are equal there will be no current. Natural ventilation, on account of its feebleness and liability to derangement by changes in the temperature of the atmosphere at the surface, is inadequate for operations of considerable extent, and recourse must be had to artificial ventilation.

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## FURNACE VENTILATION.

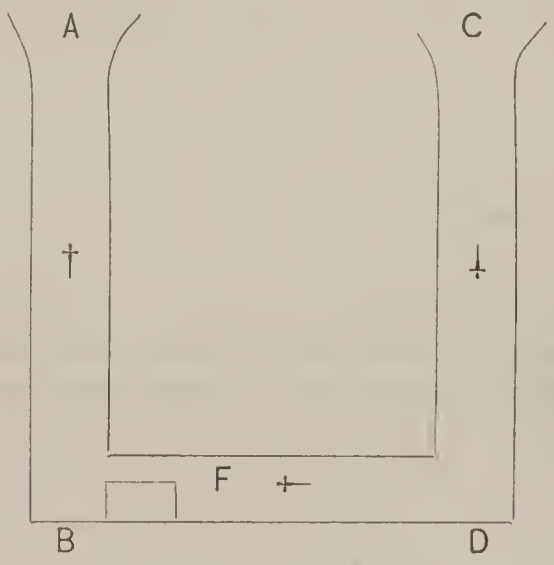
The object of a ventilating furnace is to strengthen the natural current, which it does by imparting additional heat to the upcast column, and so reducing its density When air is heated by contact with the fire, it is lightened and is no longer able to resist the pressure of the colder air behind it. The higher the temperature is raised, the greater the velocity of the current, and the larger the quantity of air obtained.

The air after passing the furnace is enlarged in volume, and, therefore, the upcast shaft should be larger than the downcast, to keep down the velocity of the current. It should also be lined and dry, so as to hold the heat. If the upcast is cold and wet, the larger it is the greater will be its cooling surface, and under such circumstances the upcast shaft should not be too large If the return current of a mine is loaded with fire-damp, or black damp, it should not be passed through the furnace, as the one may explode and the other partially extinguish the fire. In such cases, the current is carried over the furnace to the heated upcast in a "dumb drift," which enters the upcast shaft about 50 feet above the furnace ; the furnace being fed by a separate split from the surface. The furnace should be located

about 50 yards from the upcast shaft, and the furnace drift should rise 1 in 6 from the furnace to the shaft In practice the amount of air passing varies from 4000 to 8000 cubic feet per minute for every foot breadth of bars.

All other things being equal, the amount of air obtained varies as the square root of the depth of the shaft.

To illustrate one of the methods of ascertaining the amount of ventilation obtained with a furnace, in the following diagram let AB and CD be two shafts, each 459 feet deep and 10 ft. by 10 ft. connected by the air-way DB of the same size and length as either of the shafts. Let F represent location of the furnace.




Let the temperature of the downcast and air-way be 50°, and the average temperature of the upcast be 100°, then the furnace will have raised the upcast temperature 50°, and as the shaft is 459 feet deep and 459 feet of air expand one foot for every degree of heat added to it, it follows that the furnace having added 50°, will have expanded the upcast column of air 50 feet, or, to put it more plainly, the furnace has forced a quantity of air out at the top of the upcast equal to what would fill 0 feet of the shaft at a temperature of 100°.

To find the weight of this column of 50 feet, first find the weight of one foot of air at 100°, and as this varies with the pressure, as shown by a barometer, suppose the

pressure equal to 30 inches of mercury ; then find the weight by the formula : ·

$$\frac{1{\cdot}32529 \times 30\ B}{459 + 100^{\circ}} = {\cdot}0711246 \text{ lbs.} = \text{weight of one foot.}$$

As ·0711246 pounds is the weight of one foot at 100°, 50 times that amount will be the weight of the column.

·0711246
50

3·5562300 = weight of 50 ft. column.

Therefore a pressure of a little over three and one-half pounds per square foot is producing the ventilating current under these conditions.

Having found the pressure, now find the rubbing surface presented to the air, in both shafts and air-way, so as to get at the resistance which the pressure has to overcome. Each shaft 10 feet by 10 feet = 100 feet area, and the four sides, 10 feet each, make 40 feet around each shaft and air-way. This is the perimeter, which, multiplied by the length, gives the rubbing surface :

Depth, 459 feet
Perimeter, 40

Rubbing surface 18,360 square feet in each, and, as all three are one size, three times this quantity is the whole rubbing surface :

18,360
3

55,080 feet = total rubbing surface.

The next factor required is the co-efficient of friction ; that is, the pressure required to overcome the resistance of the air in rubbing against the surface of the passages of a mine exposed to the current. This is got by experiment, and has been found to vary with the character of the surfaces exposed to the current. Most authorities use the co-efficient ·0000000217 pounds pressure per square foot of area of air passage for every square foot of rubbing surface exposed to the current moving at the rate of one lineal foot per minute

If the pressure per square foot is multiplied by the area, the product will be the total pressure, = 355·623 pounds, and, if the rubbing surface is multiplied by the co-efficient

of friction, the product will be the pressure required to overcome the friction at a velocity of one foot per minute = ·0011952360 pounds. As the resistance is in proportion to the square of the velocity, if the whole pressure is divided by the pressure necessary to overcome the friction at a velocity of one foot per minute, the result will be the square of the velocity, the square root of which is the velocity itself.

$$\frac{355{\cdot}623}{{\cdot}0011952360} = 297{,}533$$

and $\sqrt{297{,}533} = 545$ feet, the velocity per minute. The velocity multiplied by the area of the air-way gives the quantity passing:

Velocity 545
100

54,500 cubic feet.

This is the work of a furnace under these conditions against friction. If there was no friction to be taken into consideration, the result would be much greater.

The power obtained by furnace ventilation is measured by the difference between the weight of the air in the downcast and upcast shafts. The length of the column in the downcast shaft, which would be equal, in weight, to the difference of the weight of the air in the two shafts, is called the *motive column.*

The motive column is usually found by the formula:

Let M = motive column,
T = temperature of upcast,
t = " " downcast,
D = depth of downcast:

$$\text{and then } M = D \frac{T - t}{T + 459}$$

In the present case it may be found by dividing the pressure per square foot, 3·55623 pounds, by the weight of one foot of the downcast air column, which, found by the formula already given, is ·0781113 pounds. The pressure per square foot divided by this = 45·52 feet, the length of the motive column.

Under these circumstances, then, the air in the downcast would balance that of the upcast with a column 45 52 feet shorter than that in the upcast. This may be taken to be a

vacuum The theoretical velocity of air in rushing into a vacuum is the same as the velocity that a falling body would attain at a depth represented by the length of the vacuum, or the velocity is 8 times the square root. In this case it would be $8\sqrt{45{\cdot}52} = \sqrt{45{\cdot}52} \times 8 = 53{\cdot}968$ feet per second, or $53{\cdot}968 \times 60 = 3{,}238{\cdot}08$ feet per minute, or $3{,}238{\cdot}08 \times 100 = 323{,}808$ cubic feet for the whole air-way. The actual current secured, therefore, is much smaller than the theoretical result, owing to the resistances the air meets with in its passage ; the amount of ventilation obtained from the motive column depending on the length and sectional areas of the air-ways.

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## FRICTION OF AIR IN MINES.

The friction of air in mines is according to certain laws, some of which have been explained as follows by Inspector Mauchline, in a paper read before the Mining Institute of Pennsylvania :

Friction is produced by something rubbing against something else, and friction in ventilation is the result of the air current rubbing against the surface of the passages through which it is moving.

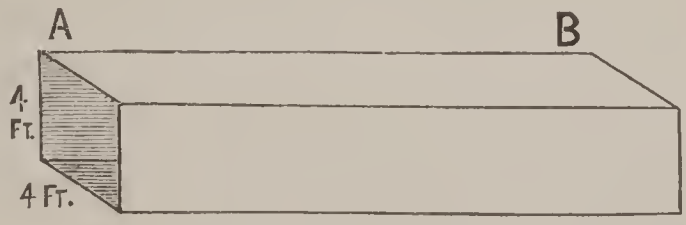


Fig 1.

When the barometer reads 30 inches the pressure on all surfaces exposed to the air is 2120·25 pounds per square foot. In figure 1, let AB represent an air-way, 4 feet wide, 4 feet high, and 1500 feet in length The amount of surface in this air-way against which the air presses as it moves along is $4 + 4 + 4 + 4 = 16$ feet for each foot of its length, and as it is 1500 feet long—the total amount of pressing surface will be 16 times 1500 or 24,000 square feet. As the pressure per square foot, as before stated, is 2120·25 pounds, the total pressure on this air-way will be 24,000

times 2120·25 or 5,128,600,000 pounds, or 25,443 tons.

If an air-way only 4 feet high, 4 feet wide, and 1500 feet long bears a pressure of 25,443 tons, it is not difficult to see where friction comes from.

Friction is the result of the air which exerts the great pressure just shown, rubbing against the surfaces of the air-ways, and it necessarily follows that it will increase or decrease as the surface of the air-ways is increased or decreased, providing the velocity at which the air is passing remains the same—that is, the friction is doubled when the surface of the air-ways is doubled, and it follows also that if the rubbing surface is doubled, the friction doubled, and the distance doubled that the air must pass over, that the total pressure putting the air in motion must also be doubled to produce the same velocity of the air column and to furnish the same quantity of air. Hence, if a given pressure is moving air in an air-way 500 yards long, and the air-way is extended to 1000 yards in length, the resisting surface will be doubled, the length the air has to pass will be doubled, and the pressure will also have to be doubled to maintain the same velocity and quantity.

This leads to the consideration of another condition as regards the extent of the resisting surface. In ventilation, pressure is measured by an instrument known as the water gauge, which is a measure of the difference of the density of the intake and return air, and consequently is a measure of the amount of pressure putting the air in circulation; that is, when an exhausting machine is used, it is a measure of how much less pressure is on the outlet than on the inlet, and when a forcing machine is used, of how much more pressure there is on the inlet than on the outlet. In speaking of pressure the terms are used which express its force on every square foot of the area of the air-way.

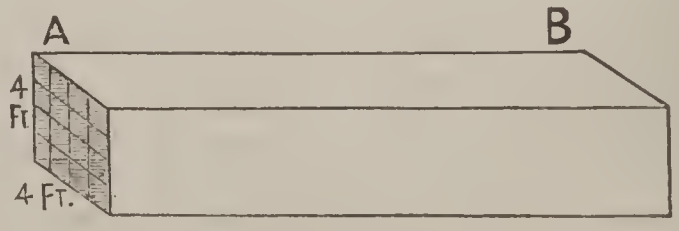


Fig. 2.

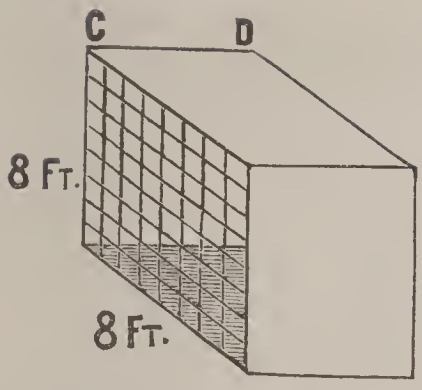


Fig. 3.

In the case of two air-ways of unequal area but of equal rubbing surface—the smaller one can be so much longer as to make up the difference—with the same total pressure the velocity will be the same, as both present the same resistance, but the total pressure spread over the larger one will be less per square foot than on the small one and the quantity or volume of air obtained will be in proportion to their areas. This principle may be illustrated by figures 2 and 3. In figure 2, let A B be an air-way 4 feet high and 4 feet wide, and 1000 yards long ; then the sum of its four sides is 16 feet, and it will have 16 square feet of rubbing surface for every foot of its length, or 48,000 square feet.

In figure 3 let the air-way C D be 8 feet high, 8 feet wide, and 500 yards long ; then the sum of its four sides will be 32 and it will have 32 square feet of rubbing surface for each foot of its length, or 48,000 square feet.

It is thus seen that the friction in both these air-ways is alike because their surfaces are equal and to move air in either at the same speed will require the same total pressure because the resistance is the same.

If they are subjected to the same total pressure and the pressure upon the large one, the area of which is 64 square feet, is 1 pound per square foot, then the pressure upon the small one, the area of which is but one-fourth as much as that of the larger or 16 square feet, will be 4 pounds per square foot.

Then, as the velocity is the same in both air-ways with the same total pressure, while the small air-way is passing ten thousand cubic feet, the large one will pass forty thousand cubic feet. Hence, the large air-way will give four times as much ventilation as the small one, with one-fourth the pressure per square foot, or one-fourth the water gauge, although the total pressure is equal for both.

If the large air-way is made as long as the small one to continue to obtain four times as much air, will require one-half the pressure per square foot that is on the small air-way or twice the total pressure. This is a forcible illustration of the great superiority of large air-ways over smaller ones.

The next law to consider is that governing friction at different velocities. If the pressure is increased, the speed of the air column and quantity of air obtained, will also be increased, but not in the same proportion. Four times the pressure will produce double the quantity ; nine times will produce three times the quantity, and sixteen times the pressure will give four times the quantity of air, and in that proportion. *The quantity of air obtained will vary as the square foot of the pressure applied*—the pressure per square foot of the area—and the pressure will vary as the square of the velocity of the air column or quantity obtained. If the pressure is reduced to one-quarter ($\frac{1}{4}$), the quantity obtained will be one-half ($\frac{1}{2}$) or the square root of ($\frac{1}{4}$), and if the pressure is reduced to one-ninth ($\frac{1}{9}$), the quantity obtained will be one-third ($\frac{1}{3}$), and in that proportion.

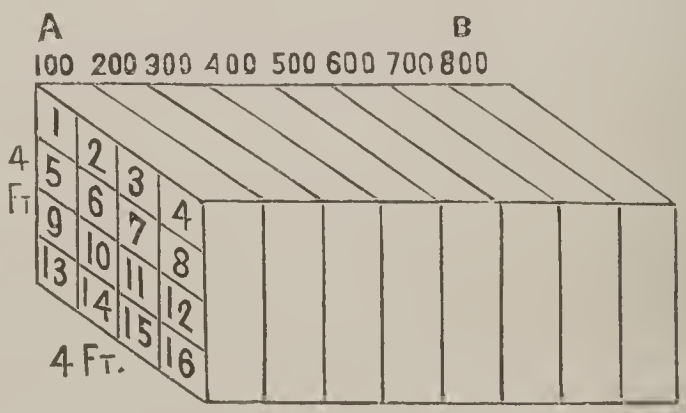


Fig. 4.

It will assist to understand the principle that the pressure required to move air, varies as the square of the velocity of the air current or the quantity obtained, to imagine an air-way with something that can be seen moving through it. Air is invisible and it is difficult to grasp a conception of its motions. In figure 4, let A B be an air-way four feet high, four feet wide, and therefore, of sixteen square feet area and eight hundred feet long, divided for illustration into eight divisions of one hundred feet each, with a column of steam moving through it at a velocity of one hundred feet per minute. Suppose the pressure putting the column of steam through the air-way be two pounds to the square foot. Imagine the column of steam to be divided into blocks of 1 cubic foot each. It will be no-

ticed that these blocks (sixteen in number), as represented in the mouth of the air-way, in moving through it, rub against its sides as follows :

| | | | | |
|---|---|---|---|---|
| Block | 1 | has | 2 sides | rubbing. |
| " | 2 | " | 1 side | " |
| " | 3 | " | 1 " | " |
| " | 4 | " | 2 sides | " |
| " | 8 | " | 1 side | " |
| " | 12 | " | 1 " | " |
| " | 16 | " | 2 sides | " |
| " | 15 | " | 1 side | " |
| " | 14 | " | 1 " | " |
| " | 13 | " | 2 sides | " |
| " | 9 | " | 1 side | " |
| " | 5 | " | 1 " | " |
| | | | = | |
| | Total, | | 16 sides | " |

or 16 square feet. Blocks 6, 7, 10 and 11 have no sides rubbing, and, therefore, create no friction. These blocks, which move at a velocity of 100 feet per minute, will every minute move the length of one division of the air-way and rub against 100 feet lineal, or 1600 square feet of rubbing surface, and in eight minutes will move the full length and rub against 800 feet lineal or 24,000 square feet, the aggregate rubbing surface. Suppose three times the quantity of steam is required. This will necessitate moving the column three times as fast. If the blocks, then, at a velocity of 100 feet per minute, moved through one division of the air-way and rubbed against 100 feet lineal, or 1600 square feet of rubbing surface, at a velocity of 300 feet per minute, they will move through three divisions of the air-way and rub against 300 feet lineal, or 4800 square feet of rubbing surface. They will thus meet with three times the rubbing surface or friction in a minute, and if the pressure per square foot was originally 2 pounds, it will have to be increased three times and raised to 6 pounds per square foot, 2 pounds $\times$ 3 = 6 pounds. But there is another force that must be taken into consideration. The blocks, instead of striking against the rubbing surface with a momentum gained from a velocity of 100 feet per minute, as in the first instance, strike against it with a momentum gained from a velocity of 300 feet per minute.

Thus, each block will also create a resistance, from the greater momentum acquired, three times greater than before, and thus require the pressure to be again increased three times, and raised from 6 lbs. per square foot to 18 lbs.; 6 lbs. $\times$ 3 = 18 lbs., or 9 times the original pressure of 2 lbs.

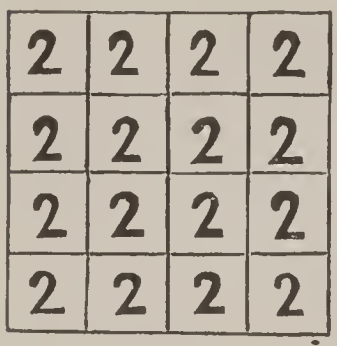


Fig. 5.

From figures 5, 6 and 7 a proper conception of the relative pressures upon the area of the air-way, made necessary by the greater friction developed by the changed conditions, may be obtained.

Figure 5 represents the area of the air-way with a pressure of 2 lbs. per square foot or a total pressure of 2 lbs. $\times$ 16 = 32 lbs.

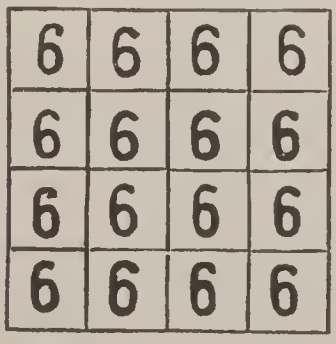


Fig. 6.

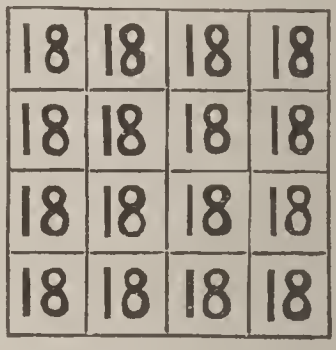


Fig. 7.

Figure 6 represents the area of the air-way, with the pressure per foot increased three times to overcome the friction developed in the triple rubbing surface passed over in the same time—one minute—which is 6 lbs. per square foot, or a total pressure of 6 lbs. $\times$ 16 = 96 lbs.

Figure 7 represents the area of the air-way, with the pressure increased three times to overcome the resistance due to the triple amount of rubbing surface passed over in the same time, and again increased three times to overcome the friction developed by the blocks striking the rubbing surface with three times the momentum attained from three times the velocity, or 3 $\times$ 3 = 9 times 2 lbs. = 18 lbs., making a total pressure of 18 lbs. $\times$ 16 = 288 lbs. *Nine is the square of three, and the pressure, therefore, varies as the square of the velocity or quantity obtained.*

Another and perhaps the most important principle involved in the friction of air in mines, is the relation between the power expended and the result obtained, or the units of work given out and the velocity or quantity of air produced. How the pressure applied to each square foot of the area is affected by changes in the velocity has been explained. It remains to explain how the power of units of work given out are affected by the velocity. It has been shown that the result or quantity obtained is in proportion to tha square root of the pressure, and that the resistance or friction developed, is in accordance with the square of the velocity or quantity obtainod, as is also, as a matter of course, the pressure necessary to overcome it.

The velocity or amount of air obtained is in proportion to the cube root of the power expended, and the power necessary is in proportion to the cube of the velocity or quantity of air obtained. It may seem strange if a fan driven by an engine of ten horse-power produces 10,000 cubic feet of air per minute, and it is desired to increase the quantity of air to 40,000 cubic feet per minute, that it will be necessary to obtain an engine of 640 horse-power or 64 times larger, but it is nevertheless true

Before this law can be understood, a proper appreciation of what is meant by the term power must be had. It is of the greatest importance that the difference in the meaning between the terms "pressure" and "power," as used in ventilation, be borne in mind. Pressure is the force on each square foot of the area of the air-way, which is overcoming the resistance, while "power" is this force multiplied by the amount of displacement it is producing or the result it is accomplishing in a given time. As explained in "Mechanics", work is the product of the force multiplied by the displacement it produces in its point of application. In this definition the force is supposed to be constant, and the point of its application to coincide with the direction of the force. In expressing the work done by a force, the units of weight lifted through a unit of height, as in pounds lifted one foot, called foot-pounds, are employed. The rate of working of a machine or the "power" it develops is expressed by the units of work done in a unit of time as in foot-pounds per minute, or in conventional units called horse-powers. One horse-power is equivalent to 33 000 foot-pounds per minute or 33,000 pounds lifted one foot high in one minute. Thus a ma-

chine that can raise 12 tons, through a height of 10 feet in two minutes, is rather more than 4 horse-powers. This may be proved as follows : 12 tons reduced to pounds is 26,880 pounds, which multiplied by 10 feet gives 268,800 pounds lifted through one foot or foot-pounds, and divided by 2 gives 134,400 pounds lifted through one foot in one minute, and this divided by 33,000, the number of foot-pounds in a horse-power, gives 4·07 horse powers.

To find the power exerted by a steam engine, the load or total pressure on the piston is multiplied by the number of feet the piston travels with the load. The result thus obtained represents the units of work or foot-pounds, and divided by 33,000, gives the number of horse-powers. On the same principle, when it is desired to find the horse-powers exerted by a fan in moving a current of air, the pressure per square foot, as represented by the difference of water level in the two columns of the water gauge reduced to pounds, is multiplied by the number of cubic feet passing per minute. This result is the units of work or foot-pounds, and divided by 33,000 gives the horse-powers exerted by the fan.

The water gauge reading simply gives the pressure expended on each square foot of the area of the air-way, and therefore the reason why the product of these two factors is the units of work requires explanation. The second factor or the quantity of air passing is found by multiplying the total area of the air-way by the velocity or the quantity passing per foot per minute. Then in the multiplication of the two factors—the water gauge reading and the quantity passing per minute—the pressure per square foot is multiplied by the number of square feet in the area of the air-way, then by the velocity or the length of the air column passing in a minute. This is the same as if the total pressure had first been found by multiplying the water gauge reading reduced to pounds by the area of the air-way, and then multiplying the result by the velocity or the length of column passing in a minute. The total pressure exerted by the fan would then represent, in the case of an engine, the load on the piston, and the length of the air column passed per minute or the velocity would represent the distance or piston speed. This may be further illustrated by an example : An air-way 2 feet high by 2 feet wide is passing 4000 cubic feet of air per minute with a pressure of 1 pound; then the units of

work are by the rule:

$$\begin{array}{r} 1 \\ 4000 \\ \hline 4000 \end{array}$$

foot-pounds per minute. But the area of the air-way is

$$\begin{array}{r} 2 \text{ ft.} \\ 2 \text{ ft.} \\ \hline \end{array}$$

4 square feet = area.

And as the pressure is 1 pound, the total pressure will be 4 pounds, and the quantity passing per minute (4000 cubic feet) divided by the total pressure, 4 pounds, will give 1000, the velocity or length of column passing in a minute. Then:

$$\begin{array}{rl} 1 \text{ lb.} & = \text{Pressure} \\ 4 & = \text{Area.} \\ = & \\ 4 & = \text{Total pressure.} \\ 1000 & = \text{Velocity.} \\ \hline 4000 & = \text{foot-pounds per minute} \end{array}$$

or the same result. The total pressure represents the weight to be lifted and the velocity or length of column passing in a minute, the height it is lifted through in a minute, and their product is converted into horse-powers by dividing it by 33,000. Hence, a fan that is working with one inch of water gauge and discharging 33,000 cubic feet of air per minute is exerting a little more than 5 theoretical horse-powers to overcome the resistance of the air at that speed, and if to do this work an engine of 10 horse-power is required, we know that 50 per cent. is wasted, in friction of the machinery and in transmission, between the boilers and the result.

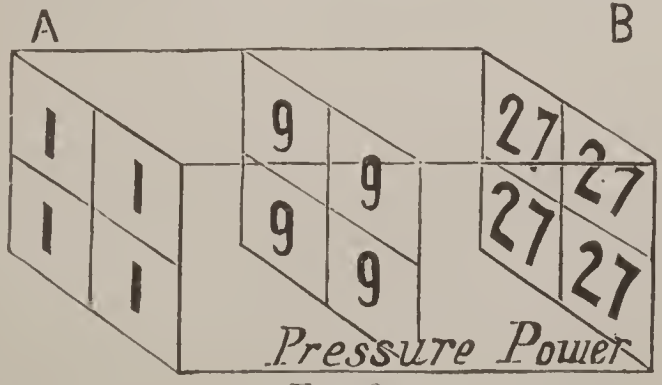


Fig. 8.

This is what is meant by power in ventilation, and that the power required varies as the cube of the velocity or quantity passing, and the velocity or quantity passing as the cube root of the power is demonstrated as follows : In figure 8, let A B represent an air-way of four square feet area, with a pressure of 1 pound per square foot, and 4 pounds total pressure, giving 1000 cubic feet of air per minute. The units of work found by multiplying the pressure by the quantity passing will be

1
1000

1000 = foot-pounds.

To put three (3) times the quantity through or 3000 cubic feet per minute, will require three (3) times the velocity. But it has been shown that three (3) times the velocity will develop nine (9) times the resistance and require nine (9) times the pressure, or the square of the increased velocity, which is nine (9), to overcome it. Hence, it follows that if the velocity is trebled that each pound of pressure in the air-way A B will have to be increased to nine (9), making a total pressure of 36 pounds. Now as the power exerted is found by multiplying the pressure by the velocity, this nine (9) times the pressure required to overcome the resistance must also be multiplied by three (3), the ratio of increase of speed. As the new pressure required is nine (9), or the square of the increased velocity, the new power required will be 27, or the cube of the new velocity.

3 = new velocity.
3

9 = square of velocity = new pressure.
3

27 = cube of velocity = new power.

In the first instance the units of work were the pressure, 1 pound, multiplied by the quantity 1000 cubic feet, making 1000 foot-pounds per minute. Now the units of work are the pressure, 9 pounds, multiplied by the quantity, 3000 cubic feet, making 27,000 foot pounds per minute; so that the increased velocity has been cubed, giving 27 times the original power or foot-pounds per minute. And if the power increases as the cube of the velocity, as a

matter of course the velocity or quantity of air obtained by different powers will vary according to their cube roots. Therefore, in case a furnace is used in ventilating, it will require eight (8) times the coal to double the quantity of air, twenty-seven (27) times to treble it, sixty-four (64) times to quadruple it, and so on in that proportion, and if a fan is used, the increase of coal necessary to raise steam will be in the same ratio, as the same law controls in both cases. The law seems complicated, but it is only the simple law of mechanics by which the power of a steam engine is found, viz : the load or resistance multiplied by the volume passing or distance traveled in a minute or any unit of time.

Mr. J. J. Atkinson, in his admirable work on "Friction of Air in Mines," says with regard to the co-efficient of friction that "for a velocity in the air of 1000 feet per minute, the friction is equal to 0·26881 feet of air column of the same density as the flowing air, which is equal to a pressure, with air at 32°, of 0·0217 pounds per square foot of area of section. Calling this the co-efficient of friction, we have the following rules with respect to the friction of air in mines.

Total pressure, $p\ a = k\ s\ v^2$. Rubbing surface, $s = \frac{p\ a}{k\ v^2}$

Square of velocity, $v^2 = \frac{p\ a}{k\ s}$

Co-efficient of friction, $k = \frac{p\ a}{s\ v^2}$

Pressure per foot, $p = \frac{k\ s\ v^2}{a}$

Area of section, $a = \frac{k\ s\ v^2}{p}$

Where $p$ = pressure per square foot ; $a$ = sectional area in feet ; $s$ = the area of rubbing surface exposed to the air ; $v$ = the velocity of the air in thousands of feet per minute, 1000 feet per minute being taken as the unit of velocity ; $k$, the co-efficient of friction in the same terms or unit as $p$ is taken.

The co-efficient varies with the nature of the rubbing

surface, and consequently may be different in the different air-passages of the same mine. The following plan may be adopted for ascertaining the friction of air in a passage: Place a gutta-percha tube of small section along the portion of the gallery of the friction of which it is desired to know; close the end of the tube fixed opposite to the current, and place a water gauge on the closure, and the instrument will then show the difference of pressure at the two extremities of the tube. Then the water gauge multiplied by $5{\cdot}2 = p$ in pounds.

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## SPLITTING THE CURRENT.

By splitting the air current, the ventilating power is economized and greater safety in the mines secured. The former will appear from what has already been said with regard to friction of air in mines. Greater safety is secured because a larger amount of ventilation is obtained with the same power, and also because the fire-damp given off from one set of workings is not passed through the others, but directly to the returns, thereby diminishing the liability of its ignition; and even should an explosion occur its effects are confined chiefly to the workings ventilated by the split in question. A minor advantage is that the velocity of the air current can be made much less, and there is less liability of the flame being forced through the gauze of the safety lamp, which happens with a velocity over 6 feet per second. Of course, the speed of the current in the main intake and returns should not be limited by the above; there will be little liability of the presence of an explosive mixture in the intake, and special rules and precautions can be taken at all times with reference to traveling in and the use of lights in the returns.

The sub-division of the air current may be carried too far, for should the current be too weak it will fail to cause the rapid mechanical mixture of the light carburetted hydrogen with the current, which is necessary to prevent a lodgment of gas in the higher parts of the workings, since diffusion acts too slowly to be of practical use. Since the air currents will pass through the various splits in such a manner that the total resistance met with is a minimum, the division should be so effected that the amount passing through each split, and the resistance met with in each

split, are the same. Although this result can only be attained in an approximate manner, still a great economy will be attained if this aim is kept in view in laying out the various workings, or rather in dividing the current among the workings.

## ASCENSIONAL VENTILATION.

By ascensional ventilation is meant the taking of the intake current at once to the lowest level in the mine, and thence leading it through the workings, always in an ascending direction. This principle is only applicable where the seams have a considerable inclination. It is based upon two considerations. *First*—The intake current is supposed to be always cooler than the return ; its temperature is gradually raised as it passes through the workings. The air current has, therefore, a natural tendency to ascend whilst passing through the workings, and by making the direction of the current to coincide with this natural tendency the current is materially assisted by the latter, whilst in the reverse direction it would be opposed by it. *Second*—In mines containing fire-damp, this being lighter than the air, it will tend to rise, and if the direction of the air current is ascensional, this tendency will help the air current to remove it ; whilst, on the other hand, if the direction of the current be downward, the natural tendency of the air to rise will oppose its removal by the air current.

In highly inclined seams, where there are numerous connections between the levels, this principle must be carefully observed, or there will be a great loss of air. Exhaustive experiments have been made in Belgium to ascertain the advantage of ascensional ventilation, and it has been demonstrated that the loss of air, where attention is not paid to it, is from 33 to 50 per cent.

## MECHANICAL VENTILATORS.

Centrifugal fans are now almost exclusively used for ventilators in this country. The *Guibal* pattern are the most popular here, as they are in England, but quite a number of the *Waddle* and the *Champion* are also in use. The *Guibal* fan is made large and runs at a moderate speed. The blades are inclined backwards, and the tips are curved

so as to be radial with the circumference. The casing has openings at the sides and an expanding chimney leading from the circumference. A vacuum is created at the centre by the revolving blades, which causes the current to pass through the openings at the sides, thence over the blades and out through the chimney. At the point where the air leaves the blades, an adjustable shutter is placed, by means of which the extent of the opening to the chimney is regulated. The *Waddle* fan receives its air at the centre of one side only, and delivers the air at the circumference. The passages for air from the centre to circumference are nicely curved, and have a gradually decreasing section, so that the velocity of rotation at any distance from the centre, multiplied by the sectional area at that distance, are constant. By this arrangement it is intended that the velocity of the air through the fan should be as uniform as possible, and the fan be kept filled to its circumference with issuing air, and the possibility of re-entries of air from the external atmosphere be prevented. The blades are inclined backwards and the whole structure revolves. The *Champion* is a double fan, working on one shaft, with the casing so arranged that it can be converted from an exhauster to a blower, or *vice versa*, without stopping or changing the motion.

Mine Inspector Gay, in a paper read before the Mining Institute of Pennsylvania, makes the following suggestions as to the construction of fans :

The most efficient pattern should be selected ; they should be built of iron, and the engines should be vertical, well-proportioned, and connected directly with the fan-shaft.

There should be an ample amount of power, so that when sixty revolutions of the fan per minute will furnish an adequate supply of air for the ordinary ventilation of the mine, it can be immediately increased to one hundred and twenty revolutions per minute, if required.

The top of the upcast should be provided with doors so arranged that in the event of an explosion they will act as a safety valve, relieving the ventilating machinery from a sudden shock. It is of the greatest importance that after an accident of this character the current be restored to its usual condition as quickly as possible, and by this arrangement the machinery will, in most instances, be secured from injury.

They should be so constructed that the currents can be

reversed, if desired, with little delay, so that in the winter months the slopes or shafts which in the warm months are downcasts, can be converted into upcasts, thereby freeing them from ice. If the fan is acting as an exhaust and a fire occurs about the top of the hoisting shaft or slope, it being the downcast, the smoke and heat are carried into the workings. This can be prevented by stopping the fan, but if the mine is a fiery one, there will be great danger of gas accumulating. If the ventilator can be quickly reversed these dangers can be avoided.

The machinery should be provided with an indicator that will show the number of revolutions made by the fan during 24 hours, a record of which can be made every evening. Many accidents have occurred through persons in charge of ventilating machinery at night not attending to their duties, and yet there have been no means of positively ascertaining such to be the fact.

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## CENTRIFUGAL FANS.

The following rules, which are applicable to small blowers for foundries and blacksmiths' fires, may be useful for approximating fans of large diameter :

D = Diameter of fan.
V = Velocity of tips of blades in feet per second.
P = Pressure in pounds per square foot.

$$V = \sqrt{P \times 676}$$

$$P = \frac{V^2}{676}$$

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## PROPORTIONS OF FANS.

$$\text{Length of vanes} = \frac{D}{4}$$

$$\text{Width of vanes} = \frac{D}{4}$$

$$\text{Diameter of inlet} = \frac{D}{2}$$

## MEASUREMENT OF VENTILATION.

Three methods have been employed for the purpose of ascertaining the velocities of the currents and the quantities of air circulating in mines.

*1. Traveling at the same velocity as the current and noting the distance passed over in a unit of time.*—This was a very primitive mode, but no doubt when used it gave a fair approximation to the truth ; for recent experiments have proved that it admitted of great accuracy for velocities up to 400 feet per minute. It was open to many objections, and would be utterly unsuited to the large mines now existing, since it would be impossible to walk as quickly as the currents travel in the principle splits, and running is not a sufficiently steady pace for the purpose. The process was as follows : Choice was made of a part of the gallery forming the air-way, having as uniform sectional dimensions as could be found, and, after measuring off a distance of a hundred or a hundred and fifty yards in length, the operator took a lighted candle, and walked in the direction of the current, fully exposing the flame to its influence, but taking care to move at such a rate that the flame would burn in an upright position without being deflected from the vertical either by the current or by the progress of the person carrying it. The time required to traverse the distance measured off being carefully noted by a seconds watch, the average rate of walking was thereby determined, and three or four trials served to give the assumed velocity of the air-current. This, multiplied by the average sectional area of the part of the air-way selected for experiment, was taken to represent the quantity of air passing in the unit of time.

*2. Determining from observation the rate at which small floating particles are carried along by the current, and assuming their velocities to be identical with that of the air-current itself.*—Until recently, observations of the velocity of the smoke from an exploded charge of gunpowder, in a part of the gallery of nearly uniform sectional area, were the means most generally adopted in coal mines for ascertaining the velocity of air-currents. They are still considerably used, and, so far as regards shaft velocities, they remain the only method. For this purpose an even part of the road should be selected, from 50 to 100 feet in length, and its cubical contents in feet ascertained. Then

let off a flash of gunpowder at the windward end of the channel, and observe the number of seconds the smoke is in passing to the other end. Then say, as the time (in seconds) in passing is to the cubic area, so is 60 seconds to the number of cubic feet passing per minute.

EXAMPLE: Length of channel selected, 50 feet; height, 7 feet; width, 7 feet; time in passing, 8 seconds. What is the amount of air?

$50 \times 7 \times 7 = 2450$ cubic feet, area; then as 8 : 2450 :: 60 : 18,375 cubic feet per minute.

Mr. F. G. Clemens, M. E., in a paper read before the May (1881) meeting of the Mining Institute of Pennsylvania, laid down the following rules for the use of gunpowder in ascertaining the velocity of air-currents in mines: *First.*—Always use one cubic inch of gunpowder. *Second.*—The velocity of the current should never be less than 100 feet a minute nor exceed 500 feet a minute. *Third.*—The time should not be less than 12 seconds nor exceed 30 seconds. *Fourth.*—Explode the gunpowder 10 feet to the windward of the first mark. Therefore, in slow currents of from 100 to 250 feet per minute velocity, the distance to be taken over which the smoke passes will be 50 feet; and for the higher velocities of from 250 to 500 feet the distance will be increased to 100 feet.

*3. With the Anemometer.*—This apparatus is of various forms and may be divided into three classes.

Those having vanes or wands made to *revolve* by the current of air impinging upon them, the rate at which they revolve being indicated by pointers on dials forming a part of the instrument. They include Biram's and others.

Instruments which are affected by the force or impulse of the wind, without being subjected to any continuous revolving motion. These include Dr. Lind's and others.

Those of a more complex character, such as Leslie's.

Biram's anemometers is in general use in this country. Each revolution of the vanes, which is registered on the dial plate, corresponds to one foot in the linear motion of the air. Then, if the velocity per minute is multiplied by the sectional area of the channel in which the anemometer is placed, the result is the number of cubic feet of air passing per minute.

These instruments do not register the actual velocity of the air, especially in feeble air currents, but the result is so nearly correct that they answer all purposes. A certain force of air is required to overcome the friction and put

the instrument in motion. The force varies with each and every instrument. Some anemometers will continue to revolve in a current as low as 30 feet a minute ; but with the most of them a velocity of 50 feet is required, and 40 feet is recommended as an average allowance to be made to start them. The formula used for true velocities is : $V = \cdot 97R + 40$.

V=True velocity.

R=Recorded revolutions.

40=Feet allowed to start anemometer.

The following rules are given for every day use:

*First.* Use the recorded revolutions of the anemometer as correct; do not bother with any formula.

*Second.* Measure always at the same time of day, say noon, when the men are at dinner, the cars at rest, the doors most likely shut, and the ventilation moving along its proper channels.

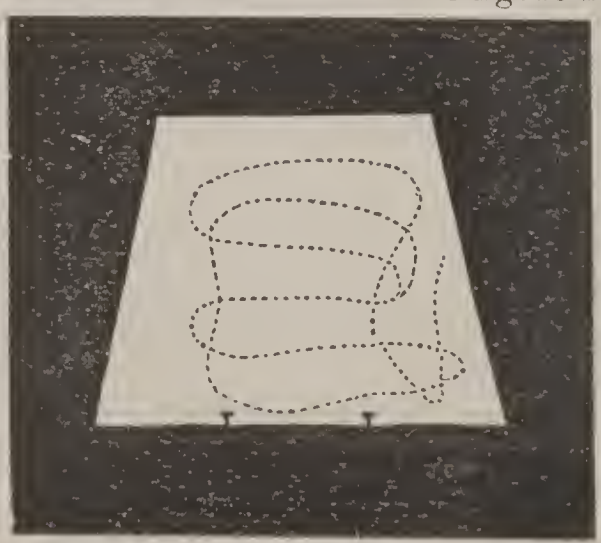
*Third.* Always use the same places in the air-ways and see that they are as regular and straight as possible.

*Fourth.* Take the record at several points, say at top, bottom and centre, and the two sides, and use the average of these records for the velocity of the current.

The following rules are used at some of the collieries in the North of England, and are printed in the front of the book, carried by the person whose duty it is to measure the air :

Rule.—Sectional area to be entered at the time of each measurement. Height $\times$ width = area.

The person measuring must hold the anemometer at arm's length in front of his body, and keep the face of the fan square to the current of air, and keep moving it slowly as per the dotted line drawn within the figure below :



[Figure showing a section of a place at which the air is measured, the dotted line to illustrate movements made by the anemometer.]

The index figures of the anemometer to be entered continuously:

1. Take the velocity for one minute and make complete entry.

2. Take the velocity for two minutes and divide by two; should the average be near the first reading, enter the average as the velocity.

In all cases add or substract, as the case requires, the correction due to the instrument.

One page of the book to be used for each measurement. Date and time of day must always be written at the top of the page, and the person measuring must sign his name at the last measurement.

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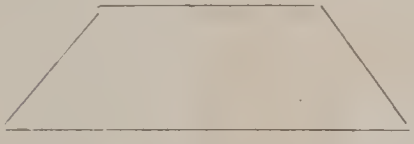
## TO FIND THE AREA OF DIFFERENT FORMS OF AIR-WAYS.

Base $\times$ Height = Area.

$\frac{1}{2}$ Base $\times$ Height = Area.



$\frac{1}{2}$ sum of two parallel Sides $\times$ Height = Area.

Diameter $\times$ 3·1416 = Circumference.

$$\frac{\text{Circumference}}{3{\cdot}1416} = \text{Diameter.}$$

Diameter $^2$ $\times$ .7854 = Area.

Side of an equal Square = Diameter $\times$ ·8862.

## TO FIND THE QUANTITY OF AIR BY THE THERMOMETER.

Temperature of air ($t$) on the outside of the current being very accurately taken, raise the temperature of the thermometer 10° above $t$, and then observe the number of seconds $s$ which elapse while the thermometer exposed to the free current of air cools to 5° of the 10°, then

$$\frac{c}{s^2} = \text{feet per second velocity,}$$

$c$ being a constant peculiar to the instrument; in one case, for example, it was 16,000. Let the bulb be very clear.

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## THE WATER GAUGE

Is used to ascertain the "drag" or resistance to the air in a mine. The resistance is found by taking the difference of density between the *intake* and *return* air. This may be done by placing the water gauge through a door erected in a passage connecting the road along which the fresh air is entering the mine and the road by which the foul air is returning. The glass tube being open at each extremity, the difference of the water-level in the two branches of the tube represents the difference of density of the intake and return air. The weight of a square foot of water one inch deep equals 5·2 pounds; therefore, for every inch there is in difference between the two branches of the tube there will be 5·2 pounds of "drag" or resistance to each square foot of the air-way; and to find the horse-power of the ventilation, multiply the quantity of air passing per minute by the "drag," and again by 5·2, and divide by 33,000.

*Example:*

What is the horse-power expended when the ventilating current measures 33,000 cubic feet per minute, and the water gauge is 0·65 ?

$$\frac{33{,}000 \times 0{\cdot}65 \times 5{\cdot}2}{33{,}000} = 3{\cdot}07 \text{ H. P.}$$

The quantity of air passing in a mine is according to the square root of the water gauge, which is the measure of the pressure of the ventilation in force. The following figures give the square root of the water gauge for every

one tenth of an inch from half an inch to three inches, and the quantity of air that will pass for each height of the water gauge, supposing 10,000 cubic feet pass when it stands at one inch, the air-courses remaining in the same condition :

| W. G. | Square root of W. G. | Quantity. | W. G. | Square root of W. G. | Quantity. |
|---|---|---|---|---|---|
| ·5 | ·7071 | 7,071 | 1·8 | 1·3416 | 13,416 |
| ·6 | ·7745 | 7,745 | 1·9 | 1·3784 | 13,784 |
| ·7 | ·8366 | 8,366 | 2· | 1·1142 | 14,142 |
| ·8 | ·8944 | 8,944 | 2·1 | 1·4491 | 14,491 |
| ·9 | ·9486 | 9,486 | 2·2 | 1·4832 | 14,832 |
| 1· | 1· | 10,000 | 2·3 | 1·5165 | 15,165 |
| 1·1 | 1·0488 | 10,488 | 2·4 | 1·5491 | 15,491 |
| 1·2 | 1·0954 | 10,954 | 2·5 | 1·5811 | 15,811 |
| 1·3 | 1·1401 | 11,401 | 2·6 | 1·6144 | 16,144 |
| 1·4 | 1·1832 | 11,832 | 2·7 | 1·6413 | 16,431 |
| 1·5 | 1·2247 | 12,247 | 2·8 | 1·6733 | 16,733 |
| 1·6 | 1·2649 | 12,649 | 2·9 | 1·7029 | 17,029 |
| 1·7 | 1·3038 | 13,038 | 3·0 | 1·7320 | 17,320 |

If it be required to know the quantity that will pass under other circumstances it may be found by rule of three. Thus supposing 20,000 feet of air pass with a water gauge of 1½ inches, what quantity will circulate with 2½ inches of water gauge ? The square root of 1½ = 1·2247 and of 2½ = 1·5811; then we say :

As 1·2247 : 20,000 :: 1·5811 : 25,820, the quantity required.

## GASES MET WITH IN MINES.

### NITROGEN GAS.

Nitrogen gas is lighter than air under the same temperature and pressure. The specific gravity of air being taken as 1000, that of nitrogen is 971·37, so that 1000 cubic feet of air weigh 80·728 pounds, and 1000 cubic feet of nitrogen 78·416 pounds, and one foot of air weighs 0·080728 pounds at 32° and 14·7 pounds pressure per square inch, one foot of nitrogen, under same conditions, weighing 0·0784167 pounds. Nitrogen gas has neither color, taste, nor smell, will not support life nor combustion, but destroys life and extinguishes lights. Its use is to dilute the oxygen of the atmosphere, and render it fit for respiration.

### OXYGEN GAS.

Oxygen forms 21 per cent. by volume, and 23 per cent. by weight, or more than one-fifth of atmospheric air. Its specific gravity is 1105·63, that of air being 1000. At a temperature of 32° and pressure of 14·7 pounds per square inch, 1000 feet weigh 89·255 pounds ; air, same conditions, 80·728 pounds. Oxygen has neither color, taste, nor smell ; red-hot wire will burn brilliantly in it, and animals die through excess of vital action.

### CARBONIC ACID GAS—BLACK DAMP.

This gas is composed of oxygen and carbon. Its chemical composition is :

| | By atoms. | By weight. | By volume. | |
|---|---|---|---|---|
| Oxygen..... | 2 | 72·73 per ct. | 1 | |
| Carbon..... | 1 | 27·27 " | 1 | |
| | 1 | 100·00 | 1 | condensed |

Carbonic acid gas is a poisonous mixture, although it contains nearly 3 out of 4 by weight of oxygen (the life-supporting element). It is dangerous to life to breathe air containing from 10 to 12 per cent of it. According to Frieberg, conditions can exist when miners will be struck down before the light is extinguished, although lights will not burn in air mixed with one-tenth of it. The breathing of this gas acts like a narcotic poison ; first exciting, then producing paralysis, and at last, by satiety, death. It is, therefore, similar to chloroform. Its specific gravity is 1528·01, that of air being 1000. At a temperature of 32° and pressure of 14·7 pounds per square inch, 1000 cubic feet of carbonic acid gas weigh 123·353 pounds. Air, same conditions, 80·728. As it is rather more than one and one-half times as heavy as common air, it is always found in the lowest levels of mines, or next the floor, except where displaced by currents or expanded by heat.

It is called by the miners "black-damp," "stythe," "choke-damp," &c. It is frequently met with ; in fact, it is not absent in any mine where the air is not continually renewed. It is produced in all collieries by the breath of the workmen (each man exhales 6·3 gallons of this gas hourly), the burning of lights, the explosion of powder, the fermentation of animal and vegetable substances, &c.

### HYDROGEN GAS.

Hydrogen has neither color, taste nor smell, and is not a supporter of combustion. If a light be plunged into a jar of it, it is extinguished. When mixed with common air or pure oxygen, it is highly explosive. Its specific gravity is 0·06927, air being 1. It is the lightest of all the gases.

### CARBURETED HYDROGEN GAS.

Carbureted hydrogen gas is chemically composed of :

| | By atoms. | By weight. | By volume. |
|---|---|---|---|
| Hydrogen..... | 2 | 24·6 per ct. | 2 |
| Carbon ..... | 1 | 75·4 " | 1 |
| | 1 | 100·0 " | 1 condensed. |

At a temperature of 32°, and under pressure of 14·7 pounds per square inch, 1000 cubic feet of it weigh 45·368 pounds ; air, same conditions, 80·728 pounds ; so that it is rather more than one-half as heavy as an equal volume of air under the same conditions.

### FIRE-DAMP.

Fire-damp is not, as commonly supposed, identical with carbureted hydrogen gas, as will appear from the following analysis :

| | Jarrow. Bensham Seam. (Playfair.) | Killing-worth. (Richardson.) | Gates-head. (Graham.) |
|---|---|---|---|
| Carbureted hydrogen..... | 83·10 | 66·30 | 94·20 |
| Light air..... | .... | 23·35 | .... |
| Nitrogen ..... | 14·20 | 6·52 | 4·50 |
| Oxygen..... | 0·40 | .... | 1·30 |
| Carbonic acid..... | 2·10 | 4·03 | .... |

Its specific gravity is 0·650. Owing to the fact that it is lighter than air, it is always found at the highest level in mines, if not disturbed by currents ; if left still, it will mix by diffusion with the surrounding atmosphere. The breathing of this gas, unmixed with air, is fatal to life ; but, when mixed with twice its own bulk of air, it may be breathed for some time without serious effects. When one part of fire-damp is mixed with thirty parts of air, by volume, it can be detected in the appearance of the flame of a lamp, which is drawn up to a point and elongated. If the mixture is increased up to two parts, in thirty,

the flame is surmounted by a blue halo, which partakes more or less of a brown color, according to the quantity of carbonic acid gas or "black-damp," which may be present along with the fire-damp. When the fire-damp forms one in thirteen of air, the mixture becomes explosive, and when ignited, is converted into a mass of flame, with little explosive force ; when the mixture is one in eight or ten of air, the explosive force is greatest. If the proportion be greater than one to eight or ten of air, the explosive force becomes gradually less, as we increase the proportion of fire-damp, until it reaches one in six of air, when it will no longer explode, but extinguishes lights. The presence of "black-damp," or of free nitrogen, in mixtures of fire-damp and air, lessens their explosive force ; one-seventh, by volume, of "black-damp" added to an explosive mixture, will render it non-explosive.

### AFTER-DAMP.

The result of an explosion of a mixture of fire-damp and air, is composed of :

| | | BY ATOMS. | | | | BY MEASURE. | |
|---|---|---|---|---|---|---|---|
| | | No. of Atoms. | | Relative Vol. per Atom. | Uncombined Volume. | Combined Volume. | Volume per cent. |
| Free Nitrogen | | 7·4 | × | 2 | = 14·8 | 14·8 | 71·2 |
| Carbonic Acid Gas | Carbon, | 1· | × | 2 | = 2· | 2. | 9·6 |
| | Oxygen, | 2· | × | 1 | = 2· | | |
| Steam | Hydrogen | 2· | × | 2 | = 4· | 4. | 19·2 |
| | Oxygen, | 2· | × | 1 | = 2· | | |
| | | | | | 24·8 | 20·8 | 100·0 |

Before the explosion there may be an excess of air or fire-damp beyond what is necessary to cause an explosion, which will remain unchanged and mixed with the after-damp. But there cannot be such an excess of air present as to render the after-damp fit for respiration, or the explosion could not take place. The limits are such that this is impossible. It assumes the appearance of a dense, misty vapor. It benumbs the faculties and produces a deadly lethargy. Where carbonic acid prevails in the mixture, a lamp will not burn. In cases where a larger

proportion of nitrogen is present, the lamp will burn as in sulphureted hydrogen, even after the miner is struck down, in this case life being extinguished before the flame.

As is seen in the table, "after-damp" contains about 71 parts free nitrogen, 9½ carbonic acid gas, and 19 parts of steam. The steam condensing after the explosion leaves, in round numbers, about 7½ parts of nitrogen and one part of carbonic acid gas out of 8½ parts. If there is more fire-damp present than is chemically changed, the explosive force is weaker, but the resultant after-damp is more deadly than when an excess of air is present in the mixture.

### CARBONIC OXIDE, THE WHITE-DAMP OF MINES.

Assuming, as before, that the atomic volume of carbon is twice that of oxygen, its composition is as follows :

| | By Atoms. | By Weight. | By Volume. |
|---|---|---|---|
| Oxygen | 1 | 56·69 | 0½ |
| Carbon | 1 | 43·31 | 1 |
| | 1 | 100·00 | 1 cond'ed. |

Its specific gravity is 975·195, that of air being 1000. At a temperature of 32° and under pressure of 14·7 pounds per square inch, one thousand cubic feet of carbonic oxide weigh 79·426 pounds. Air under same conditions will weigh 80·728 pounds. Carbonic oxide has a much more deleterious effect on the animal economy than carbonic acid. Air containing one per cent. of carbonic oxide kills warm-blooded animals, as shown by experiments of M. Felix Leblanc. Carbonic oxide is itself an inflammable gas, but does not support combustion of other bodies. It has no taste, but has a peculiar smell, and when mixed in the proportion of two of gas to five of air, it becomes explosive. It is easily kindled and burns with a blue flame, being transformed into carbonic acid by the process. This gas is, perhaps, never found in coal mines, except as the result of the burning of coal or wood, or the explosion of gunpowder. Such a proportion of this gas might be mixed with air that lights would burn, while life would become extinct.

### SULPHURETED HYDROGEN.

This gas is sometimes met with in coal mines. It is colorless, but distinguishable by its peculiar smell, which resembles that of addled eggs. It produces fainting fits and asphyxia, when present in small proportions with ai

r.

When pure, it acts as a powerful narcotic poison. It does not support combustion, but is itself inflammable and burns when mixed with air; when mixed with pure oxygen, it becomes explosive. It is composed as follows :

| | By Atoms. | By Weight. | By Volume. |
|---|---|---|---|
| Sulphur..... | 1 | 94·15 | $\frac{1}{2}$ |
| Hydrogen..... | 1 | 5·85 | 1 |
| | 1 | 100·00 | 1 cond'ed |

According to Bunsen, the specific gravity of this gas is 1178·88, that of air being assumed at 1000 under same conditions. According to some authorities, a horse died in an atmosphere which contained $\frac{1}{250}$ of its bulk of sulphureted hydrogen. It arises from the decomposition of iron pyrites in mineral springs and the excrementitious matters which accumulate on working roads which have been used for years. Water will take up three times its own bulk of it, and its presence can be detected by its blackening white lead or paper dipped in sugar of lead and dried. It explodes at a lower temperature than fire-damp, and the common Davy lamp is, therefore, not a sufficient protection. When this gas is present in the air of mines, lights will burn in the mixture, so that if its smell does not make its presence known, it may prove fatal to life before its presence is detected.

## WEIGHT AND CHEMICAL FORMULA OF THE DIFFERENT GASES MET WITH IN MINES.

| NAME OF GAS. | Chemical Formula. | Specific weight, air being 1. | Weight of a cubic foot in lbs. at 32° Fahr. |
|---|---|---|---|
| Carbureted Hydrogen..... | $CH_4$ | 0·55314 | ·04480 |
| Carbonic Oxide..... | CO | 0·96741 | ·07836 |
| Carbonic Acid..... | $CO_2$ | 1·52021 | ·12313 |
| Carbon..... | C | ·82921 | ·06716 |
| Oxygen..... | O | 1·10561 | ·08955 |
| Sulphureted Hydrogen..... | $H_2S$ | 1·17488 | ·09516 |
| Nitrogen..... | N | 0·97134 | ·07868 |
| Hydrogen..... | H | 0·06927 | ·00561 |

## QUANTITY OF AIR REQUIRED.

The quantity of air necessary to ensure sufficient ventilation in a mine has been variously estimated by the following authorities:

Mr. Herbert Mackworth : A minimum of 100 cubic feet per minute for each man and boy, for sanitary purposes alone, where there is no escape of fire-damp, and little of any other mineral gas.

Mr. T. J. Taylor : In a mine yielding no fire-damp, with from 120 to 130 persons employed, a current of 20,000 to 30,000 feet per minute, properly conveyed up to the face of the workings, and made to sweep the districts in which the people are employed. In fiery mines a much greater quantity.

Mr. Warrington W. Smith : In round numbers 100 cubic feet of air per minute may be required for the health and comfort for each person underground ; but if fire-damp be given off, say at the rate of 200 cubic feet per minute, we should need, at the very least, thirty times that amount of fresh air to dilute it, or 6000 cubic feet in addition.

Professor Phillips : In most of the fiery mines an average of 600 cubic feet per minute per collier is circulated ; and nearly 200 cubic feet per minute for each acre of waste.

Mr. Trevor F. Thomas : A man requires underground from 100 to 500 cubic feet of air per minute, depending on the condition of the mine ; a horse, 600 cubic feet ; a lamp, 10 cubic feet. For every pound of powder burnt, 700 cubic feet should be allowed.

For all anthracite mines nearly double the above estimates should be allowed, because of the much greater volume of powder smoke due to the large amount of blasting that is done.

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## TREATMENT OF PERSONS OVERCOME WITH GAS.

The most melancholy accidents are continually happening from the want of a little precaution in dealing with gas. Lives have frequently been lost because of the neglect to lower a candle into old shafts or openings before descending them. How often when one man has been overcome by black-damp have others rushed to the rescue to fall and die beside him. Their lives would have been saved had a few buckets of water been dashed down when the first man fell, and very likely his life saved also.

When any one is thus immersed in carbonic acid, suffocation takes place in a very short time. Recovery from it is slow and extremely difficult, and only practical in the case of a very short continuance in the gas. It is often followed by some days' illness, and particularly by a violent headache.

The symptoms of suffocation are the sudden cessation of respiration, of the pulsations of the heart, and of the action of all the sensory functions ; the countenance is swollen, and marked with reddish spots ; the eyes become protruded ; the features are discomposed, and the face is often livid.

The following directions for the treatment of cases of suffocation by gases, which also apply to drowning, are approved by the Royal Medical and Chirurgical Society, England :

### WHAT TO DO.

Send immediately for medical assistance, but proceed to treat the patient instantly, securing as much fresh air as possible.

The points to be aimed at are—first and immediately, the *restoration of breathing ;* and secondly, after breathing is restored, the *promotion of warmth and circulation.*

Remove the patient into fresh air, undo clothing and employ artificial respiration as per the rules given below ; use galvanic battery.

### TO RESTORE NATURAL BREATHING.

Rule 1.—*To maintain a Free Entrance of Air into the Windpipe.*—Cleanse the mouth and nostrils ; open the mouth ; draw forward the patient's tongue, and keep it forward ; an elastic band over the tongue and under the chin will answer this purpose. Remove all tight clothing from about the neck and chest.

Rule 2.—*To adjust the Patient's Position.*—Place the patient on his back on a flat surface, inclined a little from the feet upwards; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades.

Rule 3.—*To imitate the Movements of Breathing.*—Grasp the patient's arm just above the elbow, and draw the arms gently and steadily upwards, until they meet above the head (this is for the purpose of drawing air into the lungs); and

keep the arms in that position for two seconds. Then turn down the patient's arms, and press them gently and firmly for two seconds against the sides of the chest (this is with the object of pressing air out of the lungs. Pressure on the breast-bone will aid this.)

Repeat these measures alternately, deliberately, and perseveringly, fifteen times in a minute, until a spontaneous effort to respire is perceived, immediately upon which cease to imitate the movements of breathing, and proceed to INDUCE CIRCULATION AND WARMTH.

Should a warm bath be procurable, the body may be placed in it up to the neck, continuing to imitate the movements of breathing. Raise the body for twenty seconds in a sitting position, dash cold water against the chest and face, and pass ammonia under the nose. The patient should not be kept n the warm bath longer than five or six minutes.

Rule 4.—*To excite Inspiration.*—During the employment of the above method excite the nostrils wi h snuff or smelling salts, or tickle the throat with a feather. Rub the chest and face briskly, and dash cold and hot water alternately on them.

TREATMENT AFTER NATURAL BREATHING HAS BEEN RESTORED.

Rule 5.—*To induce Circulation and Warmth.*—Wrap the patient in dry blankets and commence rubbing the limbs upwards, firmly and energetically. The friction must be continued under the blankets or over the dry clothing.

Promote the warmth of the body by the application of hot flannels, bottles or bladders of hot water, heated bricks, &c., to the pit of the stomach, the armpits, between the thighs, and to the soles of the feet. Warm clothing may generally be obtained from bystanders.

On the restoration of life, when the power of swallowing has returned, a teaspoonful of warm water, small quantities of wine, warm brandy-and-water, or coffee should be given. The patient should be kept in bed, and a disposition to sleep encouraged. During reaction large mustard plasters to the chest and below the shoulders will greatly relieve the distressed breathing.

## RULES TO BE FOLLOWED BY THE BYSTANDERS IN CASE OF INJURY BY MACHINERY, WHEN SURGICAL AID CANNOT BE AT ONCE OBTAINED.

SEND FOR A PHYSICIAN.

The dangers to be feared in these cases are : *Shock or collapse, loss of blood and unnecessary suffering in the moving of the patient.*

Rule I. *In Shock*, the injured person lies pale, faint, cold, sometimes insensible, with labored pulse and breathing.

Apply external warmth by *wrapping him up* (not merely covering him over), in blankets, quilts or extra clothes. Bottles of hot water, hot bricks, (not too hot), may also be wrapped up in cloths and put to the arm-pits, along the sides, and between the feet, if they are uninjured.

If the patient has *not* been drinking, give brandy or whisky in *table-spoonful* doses, every 15 or 20 minutes—less frequently as he gets better. Food (strong soup is best) should also be given now and then.

Rule II. *Loss of Blood.* If the patient is *not* bleeding, *do not* apply any constriction to the limb, but cover the wounded part lightly with the softest rags to be had, (linen is best.)

If there is bleeding do not try to stop it by binding up the wound. *The current of blood to the part must be checked.* To do this find the artery, by its beating ; lay a firm and even compress or pad (made of cloth or rags rolled up, or a round stone or piece of wood well wrapped) *over the artery.* (See Fig. 1.) Tie a handkerchief around the limb and compress ; put a bit of stick through the handkerchief and twist the latter up until it is *just tight enough to stop the bleeding*, then put one end of the stick under the handkerchief to prevent untwisting, as in Fig. 2.

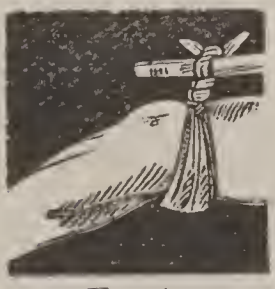

Fig 1.

Fig. 2.

The artery in the thigh runs along the inner side of the muscle in front near the bone. A little above the knee it passes to the back of the bone. In injuries at or above the knee apply the compress higher up, on the inner side of the thigh, at the point where the two thumbs meet at P, Fig. 3, with a knot on the outside of the thigh.

FIG 3, LEG.

When the leg is injured below the knee, apply the compress at the back of the thigh, just above the knee at P, Fig. 4, and the knot in front, as in Figs. 1 and 2.

The artery in the arm runs down the inner side of the large muscle in front, quite close to the bone; low down it gets further forward towards the bend of the elbow. It is most easily compressed a little above the middle. (P, Fig. 5.)

FIG. 4, LEG.

Care should be taken to examine the limb from time to time, and to lessen the compression if it becomes very cold or purple; tighten up the handkerchief again if the bleeding begins afresh.

Rule III. *To transport a wounded person comfortably.* Make a soft and even bed for the injured part of straw; folded blankets, quilts or pillows, laid on a board, with side-pieces of board nailed on, when this can be done. If possible, let the patient be laid on a door, shutter, settee or some firm support, properly covered. Have sufficient force to lift him steadily, and let those who bear him *not* keep step.

FIG. 5.

Rule IV. Should any important arteries be opened, apply the handkerchief as recommended. Secure the vessel by a surgeon's dressing forceps, or by a hook, then have a silk ligature put around the vessel and tighten tight.

Rule V. Should the bleeding be from arterial vessels of small size, apply the *persulphate of iron*, either in tincture or in powder, by wetting a piece of lint or sponge with the solution; then, after bleeding ceases, apply a compress against the parts to sustain them during the application of the persulphate of iron, and to prevent further bleeding should it occur.

The persulphate of iron should be kept on hand in or about all working places.

## SAFETY LAMPS.

Sir Humphrey Davy thus describes his invention : The principle of my lamp is, that the flame, by being supplied with only a limited quantity or air, should produce such a quantity of azotic or carbonic acid gas, as to prevent the explosion of the fire-damp ; and which, from the nature of its operations, should be rendered unable to communicate any explosion to the outer air. The wire gauze should not be more than 1-20th of an inch square ; wire from 1-40th to 1-60th of an inch is the most convenient size, and there should be 28 wires, or 784 apertures per square inch.

Stephenson describes his lamp as made to contain burnt air above the flame, and to permit the fire-damp to come in below in small quantity, to be burnt as it comes in, the burnt air preventing the passing of explosion upwards, and the velocity of the current preventing its passing downwards.

The following figures represent the illuminating power of various lamps, the standard being a wax candle, six to the pound:

| | Average number of lamps required to equal wax candle standard. |
|---|---|
| Davy's lamp, with gauze | 8·00 |
| Stephenson's lamp | 18·50 |
| Upton and Roberts' | 24·50 |
| Clanny's (glass) | 4·25 |
| Mueseler's (glass) | 3·50 |
| Parish's lamp, with gauze | 2·75 |
| Davy's lamp, without gauze | 2·50 |
| Common miner's candle, 30 to the pound. | 2·00 |

A series of experiments on safety lamps was conducted by a Committee of the North of England Institute, who thus summarize their conclusions on an inflammable vapor observed to be given off by the gauzes when heated to a high temperature :

"(1). That if a new gauze can be heated quickly to a red heat, it will, under certain circumstances, give off fumes which will inflame at that temperature. (2). That similar results can be obtained by smearing a gauze

with oil. (3). And further, that oil, on being poured over red-hot iron, will ignite.

"We may conclude, therefore, that this phenomenon is due to the presence of oil adhering to the gauze. That by heating to a high temperature, the oil is volatilized and removed, and the gauze can again be raised to a red heat without these results ; but the action returns if any oil is smeared on the gauze, and cannot be removed, except by the gauze being again heated red-hot. That the ignition of the vapor externally takes place when the gauze is inserted within a red-hot tube ; but not when a piece of red-hot iron is inserted within it.

"The gauze becomes much sooner heated red when put within the red-hot tube than when the iron is inserted within it.

"It is essential, therefore, that the gauze be rapidly heated red ; if not, the oil is volatilized without being ignited.

"We come, therefore, to the following conclusions :

"(1). That if rapidly heated to a high temperature, a safety-gauze gives off fumes which will ignite. (2). That under all known conditions under which safety lamps are used, this could not occur.

"That if a gauze be previously thoroughly acted on by caustic potash and sulphuric acid, it will not, on being heated by having a red-hot iron rod placed within it, give off fumes sufficiently inflammable to ignite on the *outside.* (There was considerable doubt about the gauze so heated firing even on the *inside.*

"The conclusion to be arrived at, therefore, is that the oil is simply attached to the outside of, and is not incorporated in the body of the iron."

Messrs. W. Smethurst, F. G. S., and James Ashworth, Mining Engineers, made a series of exhaustive experiments at the Garswood Hall Colliery, near Wigan, England, in 1878, with all descriptions of safety lamps, as to the velocity necessary to move them in an explosive mixture to cause an explosion. They report the following practical results :

1. That the greater the diameter of the gauze, the quicker will the flame pass.

2. That in an explosive atmosphere, with the low velocity of seven feet per second, and without coal dust, the Davy lamp, as ordinarily constructed, is unsafe.

3. That whatever may be the height of the tin shield, it is no protection or safeguard against the flame passing ; in fact, it adds to the danger.

4. That if a cylindrical glass shield is used, as in the Davy "Jack" lamp, and the smoke gauze made so long that the glass shield overlaps it by over a quarter of an inch, the safety of the lamp is immensely increased, and the flame will not pass until the glass is broken up by the heat, or the double thickness of gauze becomes heated sufficiently for the flame to pass.

5. That a Davy lamp, constructed after the design of Mr. Smethurst's Jack lamp, or Messrs. Ashworth and Woolrych's Jack-Davy lamp, is still safer.

6. That in many cases a Clanny lamp cannot be considered any safer than a Davy lamp, and this remark will also apply to the Bainbridge lamp.

7. That a ventilating current containing a very small percentage of gas, just enough to elongate the flame, and followed by a highly explosive body of gas, is the most severe test that a lamp can be put to, and very few can stand it.

## THE BAROMETER AND THERMOMETER.

Mercury is fourteen times heavier than water ; therefore, if the pressure of the atmosphere will balance 34 feet of water, it will only balance one-fourteenth part of that height of mercury, viz., a little more than 29 inches. When the barometer is 27·00 inches, the pressure per square foot is equal to 1908·23 pounds ; at 28·00 inches it is 1978·90 pounds ; at 29·00 inches it is 2049·58 pounds ; at 30·00 inches it is 2120·25 pounds ; and at 31·00 inches it is 2190·93 pounds. To ascertain the amount of pressure per square foot, table No. 1 (p. 103) will be useful. Thus, at 30·00 inches, the pressure, as above stated, is equal to 2120·25 pounds on each square foot of surface. For the decimal ·09 we have by table No. 1, 6·36 pounds ; 2120·25 + 6·36 = 2126·61 pounds, being the pressure on each square foot when the height of the barometer is 30·09 inches. Suppose the mercury falls from this height to 29·47 inches; then, by the table, this indicates a reduction of pressure equal to 43·81 pounds per square foot. Required the amount in cubic feet of air and gas that may be expected to be given off for each 1000 cubic feet of open space in the goaves or other waste places.

| | | |
|---|---|---|
| At 30·09 the pressure is ..... ..... | 2126·61 | pounds. |
| " 29·47 " ..... ..... | 2082·80 | " |
| Difference..... | 43·81 | " |

As 2126·61 : 43·81 :: 1000 : 20·60 cubic feet of gas, which (theoretically) may be expected to be given off by a reduction of pressure equal to that indicated above. A table of pressure is not, however, absolutely necessary for working the proportion.

| | |
|---|---|
| Height of barometer..... ..... | 30·09 |
| | 29·47 |
| Difference ..... ..... ..... | ·62 |

As 30·09 : ·62 :: 1000 : 20·60 cubic feet.

If we divide the difference by 3, we shall obtain results sufficiently accurate for all practical purposes ; thus 62 ÷ 3 = 20⅔, or 20·66 cubic feet. Considerable experience in the use of this instrument in mines has shown that its in

dications are from one to two, or even three hours behind what is actually taking place ; consequently as an instrument for warning the furnace-men to "fire-up" or the engine-tender to urge on the fan, it is worse than useless. It is, however, valuable to superintendents and other officials in the mines as an incentive to thought.

Respecting table No. 2 (p. 103), very little need be said. It shows the pressure in pounds and decimal parts of a pound for one inch, and decimal parts of an inch. The weight of a cubic foot of water = 1000 ounces ; therefore the pressure per square foot, one inch deep, will be 5·20 pounds. If the water gauge stands at ·25, or a quarter of an inch, the pressure per square foot is 1·30 pounds. For the pressure to be equal to a quarter of a pound to the square inch, or 36 pounds per square foot, the difference of the water-level must be 6·92 inches. The water gauge is very useful as a check on the furnaceman, and also a tell tale on the amount of friction in the air courses, from whence may be inferred their state and condition.

---

## THE THERMOMETER.

### TO CONVERT FAHR. INTO CENT.

Subtract 32, and divide the remainder by 1·8, thus :

$$\text{Fahr.} \frac{167 - 32}{1{\cdot}8} = 75 \text{ Cent.}$$

### TO CONVERT CENT. INTO FAHR.

Multiply by 1·8, and add 32, thus :

$$\text{Cent. } 75 \times 1{\cdot}8 + 32 = 167 \text{ Fahr.}$$

### TO CONVERT FAHR. INTO REAU.

Subtract 32, and divide by 2·25, thus :

$$\text{Fahr.} \frac{113 - 32}{2{\cdot}25} = 36 \text{ Reau.}$$

### TO CONVERT REAU. INTO FAHR.

Multiply 2·25, and add 32, thus :

$$\text{Reau. } 36 \times 2{\cdot}25 + 32 = 113 \text{ Fahr.}$$

# PRESSURE OF AIR, PER SQUARE FOOT, AS SHOWN BY THE BAROMETER AND WATER-GAUGE.

| Table No. 1. Barometer. | | Table No. 2. Water Gauge. | |
|---|---|---|---|
| In. | Lbs. | In. | Lbs. |
| 1·00 | 70·68 | 1·00 | 5·20 |
| ·99 | 69·97 | ·99 | 5·14 |
| ·98 | 69·27 | ·98 | 5·09 |
| ·97 | 68·56 | ·97 | 5·04 |
| ·96 | 67·85 | ·96 | 4·99 |
| ·95 | 67·15 | ·95 | 4·94 |
| ·94 | 66·44 | ·94 | 4·88 |
| ·93 | 65·73 | ·93 | 4·83 |
| ·92 | 65·03 | ·92 | 4 78 |
| ·91 | 64·32 | ·91 | 4·73 |
| ·90 | 62·61 | ·90 | 4·68 |
| ·89 | 62·91 | ·89 | 4·62 |
| ·88 | 62·20 | ·88 | 4·57 |
| ·87 | 61·40 | ·87 | 4·52 |
| ·86 | 60·78 | ·86 | 4·47 |
| ·85 | 60 08 | ·85 | 4·42 |
| ·84 | 59·37 | ·84 | 4·36 |
| ·83 | 58·66 | ·83 | 4·31 |
| ·82 | 57·96 | ·82 | 4·26 |
| ·81 | 57 25 | ·81 | 4·21 |
| ·80 | 56·54 | ·80 | 4·16 |
| ·79 | 55·84 | ·79 | 4·10 |
| ·78 | 55·13 | ·78 | 4·05 |
| ·77 | 54·42 | ·77 | 4·00 |
| ·76 | 53·72 | ·76 | 3 95 |
| ·75 | 53 01 | ·75 | 3·90 |
| ·74 | 52·30 | ·74 | 3·84 |
| ·73 | 51·60 | ·73 | 3 79 |
| ·72 | 50·89 | ·72 | 3·74 |
| ·71 | 50 18 | ·71 | 3 69 |
| ·70 | 49·48 | ·70 | 3·64 |
| ·69 | 48·77 | ·69 | 3·58 |
| ·68 | 48·06 | ·68 | 3 53 |
| ·67 | 47·36 | ·67 | 3·48 |
| ·66 | 46 65 | ·66 | 3 43 |
| ·65 | 45·94 | 65 | 3·38 |
| ·64 | 45·24 | ·64 | 3·32 |
| ·63 | 44·53 | ·63 | 3·27 |
| ·62 | 43·82 | ·62 | 3·22 |
| ·61 | 43 11 | ·61 | 3·17 |
| ·60 | 42·41 | ·60 | 3·12 |
| ·59 | 41·70 | ·59 | 3·06 |
| ·58 | 40·99 | ·58 | 3·01 |
| ·57 | 40·29 | ·57 | 2·96 |
| 56 | 39·58 | ·56 | 2·91 |
| ·55 | 38 87 | ·55 | 2·86 |
| ·54 | 38·17 | ·54 | 2·80 |
| ·53 | 37·46 | ·53 | 2·75 |
| ·52 | 36·75 | ·52 | 2·70 |
| ·51 | 36 05 | ·51 | 2·65 |

| Table No. 1. Barometer. | | Table No. 2. Water Gauge. | |
|---|---|---|---|
| In. | Lbs. | In. | Lbs. |
| ·50 | 35 34 | ·50 | 2·60 |
| ·49 | 34·63 | ·49 | 2·54 |
| ·48 | 33 93 | ·48 | 2·49 |
| ·47 | 33·22 | ·47 | 2·44 |
| ·46 | 3 ·51 | ·46 | 2·39 |
| ·45 | 31·81 | ·45 | 2·34 |
| ·44 | 31 10 | ·44 | 2·28 |
| ·43 | 30·39 | ·43 | 2·23 |
| ·42 | 29·69 | ·42 | 2·18 |
| 41 | 28 98 | ·41 | 2·13 |
| ·40 | 28 27 | ·40 | 2·08 |
| ·39 | 27·57 | ·39 | 2·02 |
| ·38 | 26·86 | ·38 | 1·97 |
| ·37 | 26·15 | ·37 | 1·92 |
| ·36 | 25·44 | ·36 | 1·87 |
| ·35 | 24·74 | ·35 | 1·82 |
| ·34 | 24 03 | ·34 | 1 76 |
| ·33 | 23·32 | ·33 | 1 71 |
| ·32 | 22 62 | ·32 | 1·66 |
| ·31 | 21·91 | ·31 | 1·61 |
| ·30 | 21·20 | ·30 | 1·56 |
| ·29 | 20·50 | ·29 | 1·50 |
| ·28 | 19 79 | ·28 | 1·45 |
| ·27 | 19·08 | ·27 | 1·40 |
| ·26 | 18·38 | 26 | 1·35 |
| ·25 | 17·67 | ·25 | 1·30 |
| ·24 | 16·96 | ·24 | 1·24 |
| 23 | 16·26 | ·23 | 1·19 |
| ·22 | 15·55 | ·22 | 1·14 |
| ·21 | 14·84 | ·21 | 1·09 |
| ·20 | 14·14 | ·20 | 1·04 |
| ·19 | 13·43 | ·19 | ·98 |
| ·18 | 12·72 | ·18 | ·93 |
| ·17 | 12·02 | ·17 | ·88 |
| ·16 | 11·31 | ·16 | ·83 |
| ·15 | 10·60 | ·15 | ·78 |
| ·14 | 9·90 | ·14 | ·72 |
| ·13 | 9·19 | ·13 | ·67 |
| ·12 | 8·48 | ·12 | ·62 |
| ·11 | 7·77 | ·11 | ·57 |
| ·10 | 7·07 | ·10 | ·52 |
| ·09 | 6·36 | ·09 | ·46 |
| ·08 | 5 65 | ·08 | ·41 |
| ·07 | 4·95 | ·07 | ·36 |
| ·06 | 4·24 | ·06 | ·31 |
| ·05 | 3·53 | ·05 | ·26 |
| ·04 | 2·83 | ·04 | ·20 |
| ·03 | 2·12 | ·03 | ·15 |
| ·02 | 1·41 | ·02 | ·10 |
| ·01 | ·71 | ·01 | ·05 |

## HEAT.

Quantities of heat are expressed in units of weight of water heated one degree ; as in pounds of water heated one degree Fahr.

Quantities of heat are sometimes also expressed in *units of evaporation ;* that is, units of weight of water evaporated under the pressure of one atmosphere.

Heat which evaporates 1 pound of water under one atmosphere =966·1 units of heat.

---

## THE EFFECTS OF HEAT ON DIFFERENT METALS.

| | Fahrenheit. Degrees. |
|---|---|
| Extremity of the scale of Wedgewood | uncertain. |
| Platinum melts | uncertain. |
| Wrought iron fuses | 2910 |
| Cast iron melts | 2787 |
| Welding heat of bar iron | 2420 |
| Fine gold melts | 2100 |
| Fine silver melts | 1850 |
| Copper melts | 1990 |
| Brass melts | 1870 |
| Iron red-hot in daylight | 1207 |
| Lead melts | 612 |
| Mercury boils | 600 |
| Bismuth melts | 476 |

---

## COMMUNICATION OF HEAT.

Taking the conducting power of gold at 100, the conducting powers of the undernoted bodies are as follows :

| | | | |
|---|---|---|---|
| Gold | 100·00 | Tin | 30·38 |
| Platinum | 98 10 | Lead | 17·96 |
| Silver | 97·30 | Marble | 2·34 |
| Copper | 89·82 | Porcelain | 1·22 |
| Iron | 37 41 | Brick Earth | 1·13 |
| Zinc | 36·37 | | |

## STANDARD POINTS

| | Fahr. | Cent. | Reau. |
|---|---|---|---|
| Boiling point of water under one atmosphere | 212° | 100° | 80° |
| Melting point of ice | 32 | 0 | 0 |
| Absolute zero: known by theory only, about | —461·2 | —274 | —292·2 |

9° Fahrenheit = 5° Centigrade = 4° Reaumur.

Temp Fahr. = $\frac{9}{5}$ Temp. Cent. + 32°.

" " = $\frac{9}{4}$ Temp Reau. + 32°.

Temp. Cent. = $\frac{5}{9}$ (Temp. Fahr. — 32°) = $\frac{5}{4}$ Temp. Reau.

Temp. Reau. = $\frac{4}{9}$ (Temp. Fahr. — 32°) = $\frac{4}{5}$ Temp. Cent.

---

## THE EXPANSION OF SOLIDS.

*By increasing the temperature from 32° to 212°, the length of the bar at 32° being 1·00000000.*

| | | | |
|---|---|---|---|
| Glass Tube | 1·00082800 | Gold | 1·00150000 |
| Platinum | 1·00088420 | Lead | 1·00286700 |
| Antimony | 1·00108300 | Brass | 1 00186671 |
| Cast Iron | 1·00111111 | Wrought Iron | 1·00125800 |
| Steel | 1·00118999 | Zinc | 1 00294200 |
| Blistered Steel | 1·00112500 | Spelter Solder, Brass 2, Zinc 1 | 1·00205800 |
| Steel, hardened | 1·00122502 | Soft Solder, Lead 2, Tin 1 | 1·00250800 |
| Bismuth | 1·00139200 | Copper 8, Tin 1 | 1·00181700 |
| Silver | 1·00189000 | Palladium | 1·00100000 |
| Tin | 1·00217298 | | |

---

## THE EXPANSION OF LIQUIDS IN VOLUME FROM 32° TO 212° FAHR.

| | | | | | |
|---|---|---|---|---|---|
| 1000 parts | of | Water | .... become | 1046 |
| " | " | " | Oil | " | 1080 |
| " | " | " | Mercury | " | 1018 |
| " | " | " | Spirits of Wine | " | 1110 |
| " | " | " | Air | " | 1373 |

## EXPANSION OF GASES.

*Boyle's (Mariotte's) Law.*

"The density of a gas is proportional to its pressure." Saturated steam is not a perfect gas

Perfect gases have as nearly as possible the same co-efficient of expansion under all temperatures.

P = Pressure at zero = 29·92 inches of mercury.
t = Temperature of gas
V = Volume of gas at zero.
v = Volume of gas at any temperature t.
W = Weight of gas at zero.
w = Weight of gas at any temperature t.
P = Pressure at any temperature t.
K = Co-efficent of expansion with each degree of temperature = ·002036 Fahr.

$$P = P\,(1+Kt) \qquad W = w\,(1+Kt)$$

$$v = V\,(1+Kt)$$

$$V = \frac{v}{1+Kt} \qquad w = \frac{W}{1+Kt}$$

---

## VOLUME OF A GASEOUS BODY AT DIFFERENT TEMPERATURES.

The table given, on page 107, taken from Lardner's *Handbook of Natural Philosophy*, shows the changes of volume of a gaseous body consequent on given changes of temperature. In column V are expressed in cubic inches the volumes which a thousand cubic inches of air, at 32 degrees Fahrenheit, will have at the temperature in degrees Fahrenheit expressed in column T, the air being supposed to be maintained constantly at the same pressure.

| T. | V. | T. | V. | T. | V. | T. | V. | T. | V. |
|---|---|---|---|---|---|---|---|---|---|
| —49 | 834·7 | 8 | 951·0 | 65 | 1067 3 | 122 | 1183·7 | 179 | 1300·0 |
| —48 | 836 7 | 9 | 953·1 | 66 | 1069·4 | 123 | 1185·7 | 180 | 1302·0 |
| —47 | 838·8 | 10 | 955·1 | 67 | 1061·4 | 124 | 1187·8 | 181 | 1304·1 |
| —46 | 840 8 | 11 | 957·1 | 68 | 1073·5 | 125 | 1189·8 | 182 | 1306·1 |
| —45 | 842·8 | 12 | 959·2 | 69 | 1075·5 | 126 | 1191·8 | 183 | 1308·2 |
| —44 | 844·9 | 13 | 961·2 | 70 | 1077·6 | 127 | 1193·9 | 184 | 1310·2 |
| —43 | 846·9 | 14 | 963·3 | 71 | 1079 6 | 128 | 1195·9 | 185 | 1312·2 |
| —42 | 849·0 | 15 | 965·3 | 72 | 1081·6 | 129 | 1198·0 | 186 | 1314·3 |
| —41 | 851 0 | 16 | 967·3 | 73 | 1083·7 | 130 | 1200·0 | 187 | 1316·3 |
| —40 | 853·1 | 17 | 969·4 | 74 | 1085·7 | 131 | 1202·0 | 188 | 1318·4 |
| —39 | 855 1 | 18 | 971·4 | 75 | 1087·8 | 132 | 1204·1 | 189 | 1320 4 |
| —38 | 857·1 | 19 | 973·5 | 76 | 1089·8 | 133 | 1206·1 | 190 | 1322·4 |
| —37 | 859·2 | 20 | 975 5 | 77 | 1091·8 | 134 | 1208·2 | 191 | 1324·5 |
| —36 | 861 2 | 21 | 977·6 | 78 | 1093 9 | 135 | 1210·2 | 192 | 1326 5 |
| —35 | 863·3 | 22 | 979·6 | 79 | 1095·9 | 136 | 1212·2 | 193 | 1328·6 |
| —34 | 865·3 | 23 | 981·6 | 80 | 1098·0 | 137 | 1214·3 | 194 | 1330·6 |
| —33 | 867·3 | 24 | 983·7 | 81 | 1100·0 | 138 | 1216·3 | 195 | 1332·6 |
| —32 | 869·4 | 25 | 985 7 | 82 | 1102 0 | 139 | 1218·4 | 196 | 1334 7 |
| —31 | 871 4 | 26 | 987·8 | 83 | 1104·1 | 140 | 1220·4 | 197 | 1336 7 |
| —30 | 873 5 | 27 | 998·8 | 84 | 1106·1 | 141 | 1222·4 | 198 | 1338·8 |
| —29 | 875·5 | 28 | 991·8 | 85 | 1108·2 | 142 | 1224·5 | 199 | 1340·8 |
| —28 | 877·6 | 29 | 993·9 | 86 | 1110·2 | 143 | 1226·5 | 200 | 1342·9 |
| —27 | 879·6 | 30 | 995·9 | 87 | 1112·2 | 144 | 1228·6 | 201 | 1344·9 |
| —26 | 881·6 | 31 | 998·0 | 88 | 1114·3 | 145 | 1230·6 | 202 | 1346·0 |
| —25 | 883·7 | 32 | 1000·0 | 89 | 1116·3 | 146 | 1232·7 | 203 | 1349·0 |
| —24 | 885·7 | 33 | 1002·0 | 90 | 1118·4 | 147 | 1234·7 | 204 | 1351·0 |
| —23 | 887·8 | 34 | 1004·1 | 91 | 1120·4 | 148 | 1236·7 | 205 | 1353·1 |
| —22 | 889 8 | 35 | 1006·1 | 92 | 1122·4 | 149 | 1238·8 | 206 | 1355·1 |
| —21 | 891·8 | 36 | 1008·2 | 93 | 1124·5 | 150 | 1240·8 | 207 | 1357·1 |
| —20 | 893·9 | 37 | 1010·2 | 94 | 1126·5 | 151 | 1242·9 | 208 | 1359·2 |
| —19 | 895·9 | 38 | 1012 2 | 95 | 1128·6 | 152 | 1244·9 | 209 | 1361·2 |
| —18 | 898·0 | 39 | 1014·3 | 96 | 1130·6 | 153 | 1246·9 | 210 | 1363·3 |
| —17 | 900·0 | 40 | 1016 3 | 97 | 1132·7 | 154 | 1249·0 | 211 | 1365·3 |
| —16 | 902 0 | 41 | 1018·4 | 98 | 1134·7 | 155 | 1251·0 | 212 | 1367·3 |
| —15 | 904·1 | 42 | 1020 4 | 99 | 1136·7 | 156 | 1253 0 | 213 | 1369·4 |
| —14 | 906·1 | 43 | 1022·4 | 100 | 1138 8 | 157 | 1255·1 | 214 | 1371·4 |
| —13 | 908·2 | 44 | 1024·5 | 101 | 1140·8 | 158 | 1257·1 | 215 | 1373·5 |
| —12 | 910·2 | 45 | 1026·5 | 102 | 1142 9 | 159 | 1259·2 | 216 | 1375·5 |
| —11 | 912·2 | 46 | 1028 6 | 103 | 1144·9 | 160 | 1261·2 | 217 | 1377·5 |
| —10 | 914 3 | 47 | 1030·6 | 104 | 1147·0 | 161 | 1263·3 | 218 | 1379 6 |
| — 9 | 916·3 | 48 | 1032 7 | 105 | 1149·0 | 162 | 1265 3 | 219 | 1381·6 |
| — 8 | 918·4 | 49 | 1034·7 | 106 | 1151·0 | 163 | 1267·3 | 220 | 1383·7 |
| — 7 | 920·4 | 50 | 1036·7 | 107 | 1153·1 | 164 | 1269·4 | 230 | 1404·1 |
| — 6 | 922·5 | 51 | 1038·8 | 108 | 1155·1 | 165 | 1271·4 | 240 | 1424·5 |
| — 5 | 924·5 | 52 | 1040·8 | 109 | 1157·1 | 166 | 1273·5 | 250 | 1444·9 |
| — 4 | 926 5 | 53 | 1042 9 | 110 | 1159·2 | 167 | 1275·5 | 260 | 1465·3 |
| — 3 | 928·6 | 54 | 1044·9 | 111 | 1161·2 | 168 | 1277·5 | 270 | 1485·7 |
| — 2 | 930·6 | 55 | 1046·9 | 112 | 1163·3 | 169 | 1279·6 | 280 | 1506·1 |
| — 1 | 932·7 | 56 | 1049·0 | 113 | 1165·3 | 170 | 1281·6 | 290 | 1526·5 |
| 0 | 934·7 | 57 | 1051·0 | 114 | 1167 3 | 171 | 1283·7 | 300 | 1546·9 |
| 1 | 936 7 | 58 | 1053·1 | 115 | 1169·4 | 172 | 1285·7 | 400 | 1751·0 |
| 2 | 938·8 | 59 | 1055·1 | 116 | 1171·4 | 173 | 1287·8 | 500 | 1955·1 |
| 3 | 940·8 | 60 | 1057·1 | 117 | 1173·5 | 174 | 1289·8 | 600 | 2159·2 |
| 4 | 942·9 | 61 | 1059·2 | 118 | 1175·5 | 175 | 1291·8 | 700 | 2363·3 |
| 5 | 944·9 | 62 | 1061·2 | 119 | 1177·6 | 176 | 1293·9 | 800 | 2567·3 |
| 6 | 947·0 | 63 | 1063·3 | 120 | 1179·6 | 177 | 1295·9 | 900 | 2773·5 |
| 7 | 949·0 | 64 | 1065·3 | 121 | 1181·6 | 178 | 1298·0 | 1000 | 2947·1 |

## COLORS EXPRESSIVE OF THE CORRESPONDING HIGH TEMPERATURES REDUCED TO FAHRENHEIT. (*Becquerel.*)

| | | | |
|---|---|---|---|
| Faint red | 960 | degrees | Fahr° |
| Dull red | 1290 | " | " |
| Brilliant red | 1470 | " | " |
| Cherry red | 1650 | " | " |
| Bright cherry red | 1830 | " | " |
| Orange | 2010 | " | " |
| Bright orange | 2190 | " | " |
| White heat | 2370 | " | " |
| Bright white heat | 2550 | " | " |
| Brilliant white | 2730 | " | " |
| Melting point of cast iron | 2786 | " | " |
| Greatest heat of iron blast furnace | 3300 | " | " |

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## TEMPERING STEEL.

(*Haswell.*)

Steel, in its hardest state, being too brittle for most purposes, the requisite strength and elasticity are obtained by tempering—or *letting down the temper*, as it is termed—which is performed by heating the hardened steel to a certain degree and cooling it quickly. The requisite heat is usually ascertained by the color which the surface of the steel assumes from the film of oxide thus formed. The degrees of heat to which these several colors correspond are as follows :

| | |
|---|---|
| At 430, a very faint yellow<br>At 450, a pale straw color | Suitable for hard instruments; as hammer-faces, drills, &c. |
| At 470, a full yellow<br>At 490, a brown color | For instruments requiring hard edges without elasticity; as shears, scissors, turning tools, &c. |
| At 510, brown, with purple spots<br>At 538, purple | For tools, for cutting wood and soft metals; such as plane-irons, knives, &c. |
| At 550, dark blue<br>At 560, full blue | For tools requiring strong edges without extreme hardness; as cold-chisels, axes, cutlery, &c. |
| At 600, grayish blue, verging on black | For spring-temper, which will bend before breaking; as saws, sword-blades, &c. |

If steel is heated higher than this, the effect of the hardening process is destroyed.

## STEAM, ENGINES, BOILERS, PUMPS, &C.

Steam, as the power which puts any engine into motion, may be defined as an invisible, elastic fluid, generated from water by the application of heat. It is invisible and highly elastic The point at which steam is produced in the ebullition of water is that temperature at which the tension of its vapor exactly balances the pressure of the atmosphere. A unit of heat is defined as the amount of heat necessary to raise the temperature of a pound of water one degree. To arrive at the actual temperature of steam the following formula is used:

$$1082^\circ \text{ F} + \cdot 305 \text{ T}^\circ$$

The constant number, 1082 degrees, must be increased ·305 degrees Fahrenheit for each unit of temperature, to give the total amount of heat in steam under any pressure. Steam is measured by a pressure gauge, at so many pounds per square inch, and also by atmospheres. Steam of 15 pounds pressure is of one atmosphere ; 30 pounds, two atmospheres ; 45 pounds, three atmospheres, &c. Steam of two atmospheres and above is *high-pressure* steam, and below two atmospheres *low-pressure.* Steam is taken from the boiler to the cylinder at a very high pressure, so as to give the piston a high velocity. When a certain portion of the stroke is completed, the steam is cut off and no more allowed to enter, and the stroke is finished by the elasticity of the steam already in the cylinder. Suppose steam enters any cylinder, at 60 pounds pressure per square inch, and the cylinder is 6 feet long, and that the piston performs a quarter of its stroke, or 1 foot, 6 inches ; when the steam is cut off, the remainder of the stroke will have to be completed by the steam now in the cylinder ; the pressure it will attain at half stroke will be 30 pounds ; at three-quarter stroke 20 pounds, and so on. The terminal pressure may be found by the proportion: The initial pressure is to the terminal pressure as the whole stroke is to the part of the stroke before cut off.

## DUTY OF STEAM ENGINES.

The duty of an engine is the work done in relation to the fuel consumed. This can easily be determined when its consumption of coal per actual horse-power per hour is known.

To find the duty of an engine, divide 166·32 by the number of pounds of coal consumed per actual horse-power per hour; the quotient is the duty in millions of pounds.

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## TO FIND THE HORSE-POWER OF STEAM ENGINES.

### INDICATED HORSE-POWER.

A = Area of piston in square inches.
P = Average pressure of steam in lbs. per sq. inch in cylinder.
S = Length of stroke in feet.
R = Number of revolutions per minute.
$r$ = Number of revolutions per second.

$$\text{Indicated horse-power} = \frac{2\,A\,P\,R\,S}{33{,}000} = \frac{2\,A\,P\,r\,S}{550}$$

### NOMINAL HORSE-POWER.

V = Mean velocity of piston in feet per minute.
D = Diameter of cylinder in inches.
S = Stroke of engine in feet.
H = Nominal horse-power of engine.

$$H = \frac{D^2 \sqrt[3]{S}}{15{\cdot}6} \text{ for high pressure.}$$

$$D = \sqrt{\frac{15{\cdot}6\,H}{\sqrt[3]{S}}} \qquad V = 128\sqrt[3]{S}$$

$$H = \frac{D^2 \sqrt[3]{S}}{47} \text{ for condensing engines.}$$

$$D = \sqrt{\frac{47\,H}{\sqrt[3]{S}}} \qquad V = 128\sqrt[3]{S}$$

Nominal horse-power means very little, as the actual or indicated horse-power varies in stationary engines from $2\frac{1}{2}$ to 3 times the nominal horse-power. It is becoming absolete.

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## TABLE FOR THE APPROXIMATE VELOCITIES FOR THE PISTONS OF STEAM ENGINES.

| CONDENSING ENGINES. | | | NON CONDENSING ENGINES. | | |
|---|---|---|---|---|---|
| Length of stroke in feet. | Velocity in feet per minute. | No. of revolutions per minute. | Length of stroke in feet. | Velocity in feet per minute. | No. of revolutions per minute. |
| 2 | 160 | 40 | $1\frac{1}{2}$ | 186 | 62 |
| $2\frac{1}{2}$ | $177\frac{1}{2}$ | $35\frac{1}{2}$ | 2 | 200 | 50 |
| 3 | 192 | 32 | $2\frac{1}{2}$ | $212\frac{1}{2}$ | $42\frac{1}{2}$ |
| $3\frac{1}{2}$ | 203 | 29 | $2\frac{3}{4}$ | $217\frac{1}{4}$ | $39\frac{1}{2}$ |
| 4 | 214 | $26\frac{3}{4}$ | 3 | 222 | 37 |
| $4\frac{1}{2}$ | $220\frac{1}{2}$ | $24\frac{1}{2}$ | $3\frac{1}{2}$ | 231 | 33 |
| 5 | 230 | 23 | 4 | 236 | $29\frac{1}{2}$ |
| $5\frac{1}{2}$ | 236 | $21\frac{1}{2}$ | $4\frac{1}{2}$ | 243 | 27 |
| 6 | 240 | 20 | 5 | $247\frac{1}{2}$ | $24\frac{3}{4}$ |
| 7 | 245 | $17\frac{1}{2}$ | $5\frac{1}{2}$ | 253 | 23 |
| 8 | 256 | 16 | 6 | 264 | 22 |

## THE AMOUNT OF STEAM AN ENGINE USES.

A = Area of piston in inches.
S = Stroke of engine in feet.
R = Number of revolutions per minute.
x = Ratio of admission of steam; stroke being one.
v = Specific volume of steam corresponding to the pressure of steam on admission to the cylinder.
Q = Cubic feet of steam consumed per hour, allowing for loss in passages, piston clearances, leakage, &c.
q = Cubic feet of water to be evaporated per hour.

$$Q = 1{\cdot}05\ ASRx; \qquad q = \frac{Q}{v}$$

## FRICTION OF ENGINES.

P = Pressure of steam in lbs. per sq. in. necessary to overcome the friction of an engine.
D = Diameter of cylinder in inches.

$$P = \frac{18}{\sqrt{D}}$$

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## AVERAGE PRESSURE OF STEAM IN ENGINE CYLINDERS.

| Initial Pressure, lbs. per square inch. | Average pressure of steam in lbs. per square inch for the whole stroke. | | | | | |
|---|---|---|---|---|---|---|
| | Portion of stroke at which steam is cut off. | | | | | |
| | ¾ | ⅝ | ½ | ⅜ | ¼ | ⅛ |
| 5 | 4·8 | 4·6 | 4·2 | 3·7 | 3·0 | 1·9 |
| 10 | 9·6 | 9·2 | 8·4 | 7·4 | 5·9 | 3·8 |
| 15 | 14·5 | 13·8 | 12·7 | 11·2 | 8·9 | 5·8 |
| 20 | 19·3 | 18·4 | 16·9 | 14·8 | 11·9 | 7·7 |
| 25 | 24·1 | 22·9 | 21·1 | 18·6 | 14·9 | 9·6 |
| 30 | 29·0 | 27·5 | 25·4 | 22·3 | 17·9 | 11·5 |
| 35 | 33·8 | 32·1 | 29·6 | 26·0 | 20·8 | 13·5 |
| 40 | 38·6 | 36·7 | 33·8 | 29·7 | 23·8 | 15·4 |
| 45 | 43·4 | 41·3 | 38·1 | 33·5 | 26·8 | 17·8 |
| 50 | 48·3 | 45·9 | 42·3 | 37·2 | 29·8 | 19·2 |
| 60 | 57·9 | 55·1 | 50·7 | 44·6 | 35·7 | 23·1 |
| 70 | 67·6 | 64·3 | 59·2 | 52·1 | 41·7 | 26·9 |
| 80 | 77·3 | 73·5 | 67·7 | 59·5 | 47·7 | 30·8 |
| 90 | 86·9 | 82·7 | 76·1 | 66·9 | 53·6 | 34·6 |
| 100 | 96·6 | 91·9 | 84·6 | 74·4 | 59·6 | 38·5 |
| 110 | 106·2 | 101·1 | 93·1 | 81·8 | 65·6 | 42·3 |
| 120 | 115·9 | 110·3 | 101·5 | 89·3 | 71·5 | 46·2 |
| 130 | 125·6 | 119·4 | 110· | 96·7 | 77·5 | 50·0 |
| 140 | 135·2 | 128·6 | 118·5 | 104·1 | 83·4 | 53·9 |
| 150 | 144·9 | 137·8 | 126·9 | 111·6 | 89·4 | 57·7 |
| 160 | 154·6 | 147·0 | 135·4 | 119·0 | 95·4 | 61·6 |
| 180 | 173·9 | 165·4 | 152·3 | 133·9 | 107·3 | 69·3 |
| 200 | 193·2 | 183·8 | 169·2 | 148·8 | 119·2 | 77·0 |

## WINDING ENGINES.

According to the second edition of Mr. Greenwell's *Practical Treatise on Mine Engineering*, if it be required to draw 600 tons daily from a shaft, the load, speed and power of engine may be adjusted to the depth as follows :

| Depth | Load. | Speed. Feet per second | Time of Drawing and Changing. Seconds. | Power of Engines. | | |
|---|---|---|---|---|---|---|
| | | | | Calculated. | Allowed for friction, &c. | Total. |
| Feet. | Tubs. Cwts. | | | | | |
| 300 | 2 = 16 | 10 | 40 | 33 | 17 | 50 |
| 450 | 2 = 16 | 14 | 40 | 45 | 22 | 67 |
| 600 | 2 = 16 | 18 | 40 | 58 | 29 | 87 |
| 750 | 3 = 24 | 15 | 70 | 74 | 37 | 111 |
| 900 | 3 = 24 | 18 | 70 | 88 | 44 | 132 |
| 1050 | 3 = 24 | 21 | 70 | 102 | 51 | 153 |
| 1200 | 3 = 24 | 24 | 70 | 117 | 58 | 175 |
| 1350 | 3 = 24 | 27 | 70 | 132 | 66 | 198 |
| 1500 | 3 = 24 | 30 | 70 | 146 | 73 | 219 |
| 1650 | 4 = 32 | 24 | 90 | 157 | 78 | 235 |
| 1800 | 4 = 32 | 25 | 90 | 169 | 84 | 253 |
| 1950 | 4 = 32 | 28 | 90 | 182 | 91 | 273 |
| 2100 | 4 = 32 | 30 | 90 | 196 | 98 | 294 |
| 2250 | 4 = 32 | 32 | 90 | 208 | 104 | 312 |
| 2400 | 4 = 32 | 34 | 90 | 220 | 110 | 330 |

To find the proper size for the drum or sheave :

Drum to be 10 ft. diam. for a rope of 1 in. circumference.
" 10 ft. 6 in. diam. for a rope of $1\frac{1}{4}$ in. circum.
" 11 ft. " " $1\frac{1}{2}$ "

Another rule is as follows :

Drum to be 12 feet diameter for a 10 lb. per fathom rope.
" 13 " " 12 lb. " "
" 14 " " 14 lb. " "
" 15 " " 16 lb. " "

With flat ropes, to find the point in the shaft—that is, the distance from the bottom—at which the cages meet, it is best to apply the arithmetical progression formula :

$$S = \frac{N}{2}\left\{ 2a + (N - 1)\, b \right\}$$

Where $\begin{cases} S = \text{depth of pit.} \\ N = \text{total number of revolutions.} \\ a = \text{first circumference of drum.} \\ b = \text{successive increase in circumference per revolution} = 2 \times \text{thickness of rope} \times 3{\cdot}1416. \end{cases}$

These to be all in the same denomination.

By this formula we find N the total number of revolutions. But the meeting must take place at half this number of revolutions.

Work out same formula with $\frac{N}{2}$ for N, say $n$, and the value thus found for S will be the distance from the bottom at which the cages meet.

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## TO FIND THE DIAMETER OF HOISTING DRUMS FOR FLAT ROPES.

P = Depth of pit in feet.
R = Number of revolutions of engine.
T = Thickness of rope in inches.
D = Diameter of winding barrel in feet.

$$D = \frac{12\,P - 3{\cdot}15\,R^2\,T}{37{\cdot}7\,R}$$

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## CONE DRUMS.

To find either diameter of double cone drums when one diameter, weight of rope, cage and cars, and coal are given; let

C = Weight of cage and empty cars.
M = Weight of coal or material in cars.
R = Weight of rope.
d = Small diameter.
D = Large diameter.

$$D = \frac{d\,(M + 2\,C + 2\,R)}{M + C}$$

$$d = \frac{D\,(M + 2\,C)}{M + 2\,C + 2\,R}$$

## PUMPING ENGINES.

The *power* required for pumping, according to Tredgold, is found by taking the exact height from the surface of the water to the point of discharge—adding 1½ feet for each lift for the force required to give the water the velocity, and also $\frac{1}{20}$th of the height for the friction of the piston. Call this quantity in feet H, and the diameter of pump A, in inches, then

$$\cdot 341\ H\ A^2 = \text{load in pounds,}$$

whence if P = mean effective force on the steam piston in pounds per circular inch, we have

$$D = A \left(\frac{\cdot 341\ H}{P}\right)^{1/2}$$

the diameter of piston in inches.

To find the quantity of water a pump delivers :

Let { D = diameter of pump in inches.
L = length of stroke in inches
N = number of strokes per minute.
G = number of gallons per minute delivered.

$$\text{Then } G = \frac{D^2 \times \cdot 7854 \times L}{231} \times N$$

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## TO FIND THE QUANTITY OF WATER WHICH AN ENGINE WILL PUMP FROM A GIVEN DEPTH.

H = Horse-power of engine.
Y = Depth of pit in yards.
G = Quantity of water in gallons per minute.

$$G = \frac{H \times 1319}{Y}\ ;\ Y = \frac{H \times 1319}{G}$$

$$H = \frac{Y \times G}{1319}$$

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## USEFUL NUMBERS FOR PUMPS.

D = Diameter of pump in inches.
S = Stroke of pump in inches.
$D^2 \times S \times \cdot 7854$ = cubic inches.
$D^2 \times S \times \cdot 0034$ = gallons.
$D^2 \times S \times \cdot 0004545$ = cubic feet.
$D^2 \times S \times \cdot 02833$ = lbs. fresh water.

## BOILERS.

To find the safe pressure for a single-riveted cylindrical boiler : D = diameter of boiler in inches, S = safe pressure in lbs. per square inch, T = the thickness of plate.

$$S = \frac{T \times 8900}{D} \qquad T = \frac{S \times D}{8900}$$

The constant, 8900, is very nearly equal to $\frac{M}{S} = \frac{44{,}800}{5}$

where M, the maximum tensile strength of boiler plate, is taken at 20 tons per square inch, and $5 = \frac{1}{5}$, the safe strain per square inch.

| | |
|---|---|
| Strength of plate ..... | 1 |
| Double riveted joints ..... | 0·7 |
| Single " " ..... | 0·56 |

## RELATIVE HEATING POWER OF FUEL.

(*Fritz.*)

| Fuel. | Theoretical. | Pounds of water evaporated by 1 pound of fuel. | |
|---|---|---|---|
| | | In Steam Boilers. | In Open Boilers. |
| Anthracite ..... | 12·46 | ..... | ..... |
| Coal ..... | 11·51 | 5·2 to 8 | 5·2 |
| Charcoal ..... | 10·77 | 6 to 6·75 | 3·7 |
| Coke ..... | 9·00 to 10·8 | 5 to 8 | ..... |
| Brown Coal ..... | 7·7 | 2·2 to 5·5 | 1·5 to 2·3 |
| Peat ..... | 5·5 to 7·4 | 2·5 to 4·5 | 1·7 to 2·3 |
| Wood ..... | 4·3 to 5·6 | 2·5 to 3·75 | 1·85 to 2·1 |
| Straw ..... | 3·0 | 1·86 to 1·92 | ..... |

In heating boilers on an average only 47 per cent. of the theoretical heating power of fuel is utilized, the remainder being lost through imperfect combustion, radiation and other causes.

From 13 to 20 lbs. of coal may be consumed per superficial foot of fire grate.

Three-fourths of a foot of fire grate are required to evaporate a cubic foot of water.

## THICKNESS OF BOILER IRON REQUIRED AND PRESSURE ALLOWED BY THE LAWS OF THE UNITED STATES.

PRESSURE EQUIVALENT TO THE STANDARD FOR A BOILER 42 INCHES IN DIAMETER AND $\frac{1}{4}$ INCH THICK.

| Thickness in 16ths. | DIAMETER. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 34-in. | 36-in. | 38-in. | 40-in. | 42-in. | 44-in. | 46-in. |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 5 | 169·9 | 160·4 | 152· | 144·4 | 137·5 | 131·2 | 125·5 |
| 4½ | 158·5 | 149·7 | 141·8 | 134·7 | 128·3 | 122·5 | 117·2 |
| 4 | 135·9 | 128·3 | 121·6 | 115·5 | 110 | 105· | 100· |
| 3⅔ | 124·5 | 117·6 | 111·4 | 105·9 | 100·8 | 96·2 | 92·0 |
| 3⅓ | 113·2 | 106·9 | 101·3 | 96·2 | 91·7 | 87·5 | 83·6 |
| 3 | 101·9 | 96·2 | 91·2 | 82·6 | 82·5 | 78·7 | 75·1 |

## WROUGHT IRON FLUES.

RESISTANCE TO COLLAPSING PRESSURE.

(*From Haswell.*)

| Diameter. | Length. | Thickness. | Collapsing pressure per square inch. | Diameter. | Length. | Thickness. | Collapsing pressure per square inch. |
|---|---|---|---|---|---|---|---|
| In. | Feet. | In. | lbs. | In. | Feet. | In. | lbs. |
| 6 | 10 | $\frac{1}{4}$ | 417 | 11½ | 12 | $\frac{5}{16}$ | 197 |
| 6½ | 10 | $\frac{5}{16}$ | 385 | 11½ | 12 | $\frac{1}{4}$ | 368 |
| 7 | 10 | $\frac{5}{16}$ | 357 | 12 | 15 | $\frac{1}{4}$ | 239 |
| 7½ | 10 | $\frac{5}{16}$ | 542 | 12 | 15 | $\frac{5}{16}$ | 415 |
| 8 | 10 | $\frac{5}{16}$ | 312 | 12½ | 15 | $\frac{1}{4}$ | 229 |
| 8½ | 10 | $\frac{5}{16}$ | 478 | 13 | 15 | $\frac{5}{16}$ | 384 |
| 9 | 10 | $\frac{5}{16}$ | 278 | 13½ | 15 | $\frac{1}{4}$ | 212 |
| 9½ | 10 | $\frac{5}{16}$ | 427 | 14 | 18 | $\frac{5}{16}$ | 305 |
| 10 | 12 | $\frac{5}{16}$ | 227 | 14½ | 18 | $\frac{1}{4}$ | 168 |
| 10 | 12 | $\frac{5}{16}$ | 612 | 15 | 20 | $\frac{5}{16}$ | 276 |
| 10½ | 12 | $\frac{5}{16}$ | 337 | 15½ | 20 | $\frac{1}{4}$ | 152 |
| 11 | 12 | $\frac{5}{16}$ | 206 | 16 | 20 | $\frac{5}{16}$ | 231 |
| 11 | 12 | $\frac{5}{16}$ | 557 | .... | .. | .. | ... |

# SHELLS OF BOILERS.

## RESISTANCE TO INTERNAL OR BURSTING PRESSURE.

(*From Haswell.*)

| Diameter. | Thickness. | Bursting Pressure per square inch. | | Diameter. | Thickness. | Bursting Pressure per square inch. | |
|---|---|---|---|---|---|---|---|
| | | Single Riveted. | Double Riveted. | | | Single Riveted. | Double Riveted. |
| Feet. | In. | lbs. | lbs. | Feet. | In. | lbs. | lbs. |
| 2 | 1/4 | 573 | 745 | 7·6 | 5/16 | 191 | 248 |
| 2 6 | 1/4 | 458 | 596 | 7·6 | 3/8 | 229 | 298 |
| 3 | 1/4 | 382 | 496 | 8 | 5/16 | 179 | 233 |
| 3·4 | 1/4 | 318 | 414 | 8 | 3/8 | 215 | 279 |
| 3·4 | 5/16 | 398 | 518 | 8·6 | 5/16 | 168 | 219 |
| 3·6 | 1/4 | 327 | 426 | 8·6 | 3/8 | 202 | 263 |
| 3 6 | 5/16 | 409 | 532 | 9 | 5/16 | 159 | 207 |
| 4 | 1/4 | 286 | 372 | 9 | 3/8 | 191 | 248 |
| 4 | 5/16 | 358 | 465 | 9·6 | 5/16 | 150 | 196 |
| 4 6 | 1/4 | 254 | 331 | 9·6 | 3/8 | 181 | 235 |
| 4·6 | 5/16 | 318 | 413 | 10 | 5/16 | 143 | 186 |
| 5 | 1/4 | 229 | 298 | 10 | 3/8 | 172 | 224 |
| 5 | 5/16 | 286 | 372 | 10 | 1/2 | 229 | 298 |
| 5·6 | 1/4 | 208 | 270 | 10·6 | 5/16 | 136 | 177 |
| 5·6 | 5/16 | 260 | 338 | 10·6 | 3/8 | 163 | 212 |
| 5·6 | 3/8 | 312 | 406 | 10·6 | 1/2 | 218 | 284 |
| 6 | 1/4 | 191 | 248 | 11 | 3/8 | 156 | 203 |
| 6 | 5/16 | 239 | 311 | 11 | 1/2 | 208 | 271 |
| 6 | 3/8 | 286 | 372 | 11·6 | 3/8 | 149 | 194 |
| 6·6 | 5/16 | 220 | 287 | 11·6 | 1/2 | 199 | 259 |

Such allowances for wear of the plates, oxidation, etc., are to be made, as the character of the metal, the nature of the services and the circumstances of using fresh or salt water, etc., will render necessary.

In riveted plates it is customary to estimate the safe tensile resistance of a boiler or tube, when exposed to salt water, at one fifth of its bursting pressure ; and, when exposed to fresh water alone, at one-fourth of it.

## WEIGHT AND THICKNESS OF BOILER IRON.

| | | | | | |
|---|---|---|---|---|---|
| $\frac{1}{8}$ | inch | weighs | 5 | pounds | per square foot. |
| $\frac{3}{16}$ | " | " | $7\frac{1}{2}$ | " | " |
| $\frac{1}{4}$ | " | " | 10 | " | " |
| $\frac{5}{16}$ | " | " | $12\frac{1}{2}$ | " | " |
| $\frac{3}{8}$ | " | " | 15 | " | " |
| $\frac{7}{16}$ | " | " | $17\frac{1}{2}$ | " | " |
| $\frac{1}{2}$ | " | " | 20 | " | " |

| | | | |
|---|---|---|---|
| No. 1 | Iron is | $\frac{5}{16}$ | inch thick. |
| No. 3 | " | $\frac{9}{32}$ | " |
| No. 4 | " | $\frac{1}{4}$ | " |
| No. 5 | " | $\frac{7}{32}$ | " |
| No. 7 | " | $\frac{3}{16}$ | " |

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## RULES FOR HEATING AND GRATE SURFACES.

G = Fire grate surface in square feet.
P = Number of nominal horse-power.
h = Heating surface in square yards.

$$P = \sqrt{h\,G} \qquad G = \frac{P^2}{h}$$

$$h = \frac{P^2}{G}$$

For each nominal horse-power a boiler requires :
1 cubic foot of water per hour.
1 square yard of heating surface.
1 square foot of fire grate surface.
1 cubic yard capacity.
28 square inches flue area ; 18 inches over bridge.

For cylindrical double-flued boilers an approximate rule is :

$$\frac{\text{Length} \times \text{Diameter}}{6} = \text{Nominal H. P.}$$

*Conclusions.*—No fixed rule can be established as to the best relative proportions of grate, fire box and tube surfaces,

When the quantity of fuel burnt is 50 or 60 pounds per square foot of grate bar per hour, the combustion is nearly perfect ; but loss results from carbonic oxide passing away unconsumed with hard firing.

A large increase in heating surface in proportion to coal burnt only slightly increases the economical effect.

## SOME NOTES ON BOILERS.

To avoid the too rapid contraction of a boiler, it should never be blown off till the water has cooled to 150° Fahr.

When the engine is started after standing some time, there is danger of the too rapid generation of the steam in the boiler resulting from lessened pressure ; the steam should, therefore, be let down considerably below the safety-valve pressure when the engine stops.

When steam issues from the boiler, mixed with water, the boiler is said to prime, caused by impure water, fierce ebullition, &c. The remedies are to blow off steam, and to put a grating in the boiler for the spray to strike against when trying to find its way out.

Scale and incrustation are to be avoided, as they cause the burning of the plates, the scale being a bad conductor of heat ; also when the plates get red-hot the scale separates from the plates, steam is suddenly generated, and the softened iron gives way. Scale consists of salts, gypsum, lime, &c., and is prevented by the introduction of certain substances, such as caustic soda, &c.

Boiler explosions may be due to defective material ; to bad construction; to overpressure, due to neglect; or to the safety-valve sticking; to leakages, generally at the rivets, or blowoff; to rapid feeding of cold water, causing sudden and local contraction.

## HINTS TO FIREMEN.

Do not get up steam too quickly. It hogs the furnace tubes, leads to grooving, strains the end plates, and sometimes rips the rim seams of rivets at the bottom of the shell. Fire regularly. Keep as thick a fire as the quality of the coal will allow. Do not rouse the fire with a rake. Should the coal cake together, run a slicer in on the top of the bars, and gently break up the burning mass.

Set the feed valve so as to give a constant supply and keep the water up to the height indicated by the water level pointer. There is no economy in keeping a great depth of water over the furnace crowns ; while the steam space is reduced thereby, and the boiler rendered more liable to prime. Nor is there any economy in keeping a very little water over the furnace crowns, while the furnaces are thereby rendered more liable to be laid bare.

Do not place entire confidence in a glass water gauge, unless you know that the passages are entirely unobstructed. It does not follow that there is plenty of water in the boiler because there is plenty of water in the gauge glass. Also empty gauge glasses are sometimes mistaken for full ones, and explosions have resulted therefrom. Examine the test taps frequently and thoroughly, and see that the passages are clear. Compare the steam gauge and safety-valve frequently.

Lift each safety-valve by hand in the morning before setting to work, to see that it is free. If there is a low-water safety-valve, test it occasionally by lowering the water to see that the valve begins to blow at the right point. When the boiler is laid off, examine the float and lever and see that they are free, and that they give the valve the full rise. If safety-valves are allowed to go to sleep they may get set fast.

Do not empty the boiler under steam pressure, but cool it down with the water in. If a boiler is blown off under steam pressure, the plates and brickwork are left hot. The hot plates harden the scale, and the hot brick work hurts the boiler. Cold water dashed on to hot plates will cause severe straining by local contraction, sometimes sufficient to fracture the seams.

## GIFFARD'S INJECTOR.

Q = Quantity of water injected in gallons per hour.
P = Pressure of steam in atmospheres.
D = Diameter of throat in inches.

$$D = \cdot 0158 \sqrt{\frac{Q}{\sqrt{P}}}$$

$$Q = \sqrt{P} (63 \cdot 4\ D)^2$$

| Diameter of throat in decimals of an inch. | Delivery in Gallons per hour with a pressure per square inch of | | | | |
|---|---|---|---|---|---|
| | 30 | 45 | 60 | 75 | 90 |
| ·1 | 56 | 69 | 80 | 89 | 98 |
| ·15 | 127 | 156 | 180 | 201 | 221 |
| ·2 | 226 | 278 | 321 | 360 | 393 |
| ·25 | 354 | 434 | 502 | 561 | 615 |
| ·3 | 505 | 624 | 722 | 807 | 884 |

## PRESSURE OF STEAM AT DIFFERENT TEMPERATURES.

*Results of Experiments made by the Franklin Institute.*

| Pressure in inches of mercury. | Temperature in degrees Fahr. | Pressure in inches of mercury. | Temperature in degrees Fahr. | Pressure in inches of mercury. | Temperature in degrees Fahr. |
|---|---|---|---|---|---|
| 30 | 212° | 135 | 298·5° | 225 | 331° |
| 45 | 235 | 150 | 304·5 | 240 | 336 |
| 60 | 250 | 165 | 310 | 255 | 340·5 |
| 75 | 264 | 180 | 315·5 | 270 | 345 |
| 96 | 275 | 195 | 321 | 285 | 349 |
| 105 | 284 | 210 | 326 | 300 | 352·5 |
| 120 | 291·5 | | | | |

# THE ELASTIC FORCE OF STEAM AND CORRESPONDING TEMPERATURE OF THE WATER WITH WHICH IT IS IN CONTACT.

(*From Haslett.*)

| Pressure on a Square Inch. | Elastic Force in Inches of Mercury. | Temperature of Water in Degrees of Fahrenheit. | Volume of Steam compared with the Volume of Water. | Pressure on a Square Inch. | Elastic Force in Inches of Mercury. | Temperature of Water in Degrees of Fahrenheit. | Volume of Steam compared with the Volume of Water. |
|---|---|---|---|---|---|---|---|
| lbs. | | | | lbs. | | | |
| 14·7 | 30·00 | 212·0 | 1700 | 68 | 138·72 | 304·4 | 419 |
| 15 | 30·60 | 212·8 | 1669 | 70 | 142·80 | 306·4 | 408 |
| 16 | 33·64 | 216·3 | 1573 | 72 | 146·88 | 308·4 | 398 |
| 18 | 36·72 | 222·7 | 1411 | 74 | 150·96 | 310·3 | 388 |
| 20 | 40·80 | 228·5 | 1281 | 76 | 155·06 | 312·2 | 379 |
| 22 | 44·88 | 233·8 | 1174 | 78 | 159·14 | 314·0 | 370 |
| 24 | 48·96 | 238·7 | 1084 | 80 | 163 22 | 315·8 | 362 |
| 26 | 53 04 | 243 3 | 1007 | 82 | 167 30 | 317 6 | 354 |
| 28 | 57·12 | 247·6 | 941 | 84 | 171·38 | 319·3 | 346 |
| 30 | 61·21 | 251·6 | 883 | 86 | 175·46 | 321·0 | 339 |
| 32 | 65·28 | 255·5 | 833 | 88 | 179·54 | 322·6 | 332 |
| 34 | 69·36 | 259·1 | 788 | 90 | 183·62 | 324·3 | 325 |
| 36 | 73·44 | 262·6 | 748 | 92 | 187·70 | 325·9 | 319 |
| 38 | 77·52 | 265·9 | 712 | 94 | 191·78 | 327·5 | 313 |
| 40 | 81·60 | 269·1 | 679 | 96 | 195·86 | 329 0 | 307 |
| 42 | 85·68 | 272·1 | 649 | 98 | 199·92 | 330·5 | 301 |
| 44 | 89 76 | 275·0 | 622 | 100 | 204·01 | 332·0 | 275 |
| 46 | 93·84 | 277·8 | 598 | 110 | 224·40 | 339·2 | 271 |
| 48 | 97·92 | 280 5 | 575 | 120 | 244·82 | 345·8 | 251 |
| 50 | 102·00 | 283 2 | 554 | 130 | 265 23 | 352·1 | 233 |
| 52 | 106·08 | 285·7 | 534 | 140 | 285·61 | 357·9 | 218 |
| 54 | 110 16 | 288·1 | 516 | 150 | 306 03 | 363·4 | 205 |
| 56 | 114·24 | 290 5 | 500 | 160 | 326·42 | 368·7 | 193 |
| 58 | 118·32 | 292·9 | 484 | 170 | 346·80 | 373·6 | 183 |
| 60 | 122·40 | 295·6 | 470 | 180 | 367·25 | 378·4 | 174 |
| 62 | 126·48 | 298·1 | 456 | 190 | 387·61 | 382·9 | 166 |
| 64 | 130·56 | 300 3 | 443 | 200 | 408·04 | 387 3 | 158 |
| 66 | 134·64 | 302·4 | 431 | ..... | ..... | ..... | ..... |

# WATER.

## TO FIND THE WEIGHT OF WATER IN PIPES OF ANY DIAMETER 1 FOOT LONG.

1st. Square the diameter in inches, and divide by 3.

2d (more correctly). Square the diameter in inches, and multiply by 34.

In the two following tables the weight of water has been reckoned at 10 pounds per gallon.

TABLE OF THE WEIGHT OF WATER CONTAINED IN A FATHOM OF PIPES OF ANY DIAMETER; ALSO THE NUMBER OF GALLONS.

| Diameter in inches. | weight in lbs. | No. of Gallons. |
|---|---|---|
| ½ | 0·51 | ·051 |
| 1 | 2·0 | ·20 |
| 2 | 8·1 | ·81 |
| 3 | 18·3 | 1·83 |
| 4 | 32·6 | 3·26 |
| 5 | 51·0 | 5·10 |
| 6 | 73·4 | 7·34 |
| 7 | 99·9 | 9·99 |
| 8 | 130·5 | 13·05 |
| 9 | 165·2 | 16·52 |
| 10 | 204·0 | 20·40 |
| 11 | 246·8 | 24·68 |
| 12 | 293·7 | 29·37 |
| 13 | 344·7 | 34·47 |
| 14 | 399·8 | 39·98 |
| 15 | 459·0 | 45·90 |
| 16 | 522·2 | 52·22 |
| 17 | 589·5 | 58·95 |
| 18 | 660·9 | 66·09 |
| 19 | 736·4 | 73·64 |
| 20 | 816·0 | 81·60 |
| 21 | 899·6 | 89·96 |
| 22 | 987·3 | 98·73 |
| 23 | 1079·1 | 107·91 |
| 24 | 1175·0 | 117·50 |

The following simple rule will be found useful to ascertain the weight of water in pipes: Square the diameter in inches; the result will be the weight in pounds avoirdupois in a 3-ft. length.

## TABLE SHOWING THE WEIGHT IN POUNDS, AND MEASURE IN GALLONS, OF WATER CONTAINED IN WELLS AND PITS OF ANY DIAMETER, FOR ONE FOOT IN DEPTH.

NOTE.—The number of gallons is found by squaring the diameter in feet, and multiplying by 4·895 (the number of gallons in a cylinder 1 ft. diameter and 1 ft. deep.

| Diameter. Ft. In. | Measure in Gallons. | Weight in lbs. |
|---|---|---|
| 2 0 | 19·580 | 195·80 |
| 2 6 | 30·594 | 305·94 |
| 3 0 | 44·055 | 440·55 |
| 3 6 | 60·964 | 609·64 |
| 4 0 | 78·320 | 783·20 |
| 4 6 | 99·124 | 991·24 |
| 5 0 | 122·375 | 1,223·75 |
| 6 0 | 176·220 | 1,762·20 |
| 7 0 | 239·855 | 2,398·55 |
| 8 0 | 313·280 | 3,132·80 |
| 9 0 | 396·495 | 3,964·95 |
| 10 0 | 489·500 | 4,895·00 |
| 11 0 | 592·295 | 5,922·95 |
| 12 0 | 704·880 | 7,048·80 |
| 13 0 | 827·255 | 8,272·55 |
| 14 0 | 959·420 | 9,594·20 |
| 15 0 | 1101·375 | 11,013·75 |
| 16 0 | 1253·120 | 12,531·20 |
| 17 0 | 1414·655 | 14,146·55 |
| 18 0 | 1585·980 | 15,859·80 |
| 19 0 | 1767·095 | 17,670·95 |
| 20 0 | 1958·000 | 19,580·00 |

## TO ASCERTAIN THE NUMBER OF GALLONS CONTAINED IN ANY CISTERN,

THE CUBIC CONTENTS HAVING BEEN FOUND.

Contents in cubic feet × 7·48
Or, contents in cubic inches × ·00433

Or, $\frac{\text{Contents in cubic inches}}{231}$

## TO ASCERTAIN THE PRESSURE OF WATER IN PIPES AT VARIOUS DEPTHS.

RULE.

$$\frac{\text{Head of water in feet} \times 62{\cdot}5}{144} = \text{pressure in lb. per sq. in.}$$

EXAMPLE.—What is the pressure per square inch on a pipe having a head of water of 30 feet?

$$\frac{30 \times 62{\cdot}5}{144} = 13{\cdot}02 \text{ pounds.}$$

As it has been found by experiment that a cast-iron pipe 15 inches diameter, ¾ inch thick, will be sufficiently strong for a head of 600 feet, the following rule is given to ascertain the thickness of metal in a pipe, when its diameter and the head of water are given.

$$\frac{\text{Head of water in ft.} \times \text{size of pipe in in.} \times \frac{3}{4}}{9000} = \text{thickness of metal in inches.}$$

## TABLE SHOWING THICKNESS OF METAL AND WEIGHT PER 12 FEET LENGTH FOR DIFFERENT SIZES OF PIPE UNDER VARIOUS HEADS OF WATER.

| Size. | 50 Feet Head. | | 100 Feet Head. | | 150 Feet Head. | | 200 Feet Head. | | 250 Feet Head. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thickness of Metal. | Weight per Length. | Thickness of Metal. | Weight per Length. | Thickness of Metal. | Weight per Length. | Thickness of Metal. | Weight per Length. | Thickness of Metal. | Weight per Length. |
| 2 | ·2946 | 63 | ·3126 | 67½ | ·33 6 | 72 | ·3486 | 76½ | ·3666 | 81 |
| 3 | ·3449 | 144 | ·3539 | 149 | ·3629 | 153 | ·3719 | 157 | ·3809 | 161 |
| 4 | ·3612 | 197 | ·3734 | 204 | ·3852 | 211 | ·3972 | 218 | ·4092 | 226 |
| 6 | ·3938 | 315 | ·4118 | 330 | ·4298 | 345 | ·4478 | 361 | ·4658 | 377 |
| 8 | ·4224 | 445 | ·4504 | 475 | ·4744 | 502 | ·4984 | 529 | ·5224 | 557 |
| 10 | ·4590 | 600 | ·4890 | 641 | ·5190 | 682 | ·5490 | 723 | ·5790 | 766 |
| 12 | ·4916 | 768 | ·5276 | 826 | ·5636 | 885 | 5996 | 944 | ·6356 | 1004 |
| 14 | ·5242 | 952 | ·5662 | 1031 | ·6082 | 1111 | ·6502 | 1191 | ·6922 | 1272 |
| 16 | ·5801 | 1215 | ·6048 | 1253 | ·6528 | 1360 | ·7008 | 1463 | ·74 8 | 1568 |
| 18 | ·5894 | 1370 | ·6434 | 1500 | ·6974 | 1630 | 7514 | 1761 | ·8054 | 1894 |
| 20 | ·6220 | 1603 | ·6820 | 1763 | ·7420 | 1924 | ·8020 | 2086 | ·8620 | 2248 |
| 24 | ·6870 | 2120 | ·7592 | 2349 | ·8312 | 2580 | ·9032 | 2811 | 9752 | 3045 |
| 30 | ·7850 | 3020 | ·8750 | 3376 | ·9650 | 3735 | 1 0550 | 4095 | 1·1450 | 4458 |
| 36 | ·8828 | 4070 | ·9908 | 4581 | 1·0988 | 5096 | 1·2068 | 5613 | 1 3148 | 6133 |
| 48 | 1·0784 | 6616 | 1·2224 | 7521 | 1·3664 | 8431 | 1·5104 | 9340 | 1·6544 | 10269 |

Two-inch pipe in 9 feet lengths.

# STRENGTH OF MATERIALS.

## ROPES AND CHAINS.

Cohesion of hemp fibres = 6400 lbs. per square inch of transverse section. For *safe load*, multiply the square of the girth by 200, and the product will be the strain in lbs. For cables × 120 instead of 200. For *utmost strength*, take one-fifth of the square of the girth to express the tons it will carry. Tarred cordage is always weaker than white; for, according to Du Hamel, white is one-third more durable, retains its force much longer while kept in store, and resists the ordinary injuries of the weather one-fourth longer.—(*Gregory.*) The greatest stress on a rope should not be above 700 times its weight per fathom.—(*Tredgold.*)

The mean of a variety of Ropemaker's Cards gives the following approximate rule:

| | Breaking strain. | |
|---|---|---|
| For hemp ropes (flat or round) | 1 ton | for each lb. per fathom. |
| " iron wire ropes, nearly | 2 tons | |
| " steel wire ropes, nearly | 3 tons | |

The working load is from one-fifth to one-seventh of breaking strain.

## WEIGHT AND STRENGTH OF FLAT ROPES.

| STEEL WIRE. | | IRON WIRE. | | HEMP OF EQUIV'T STRENGTH. | | | |
|---|---|---|---|---|---|---|---|
| Size in inches. | Wght per fath. | Size in inches. | Wght per fath. | Size in inches. | Wght per fath. | Working load. | Breaking strain. |
| Inches. | lbs. | Inches. | lbs. | Inches. | lbs. | Cwts. | Tons. |
| $3\frac{1}{4}$ by $\frac{5}{8}$ | 18 | $4\frac{1}{2}$ by $\frac{7}{8}$ | 30 | $8\frac{1}{2}$ by $2\frac{1}{4}$ | 45 | 120 | 46 |
| 3 " $\frac{5}{8}$ | 16 | $4\frac{1}{4}$ " $\frac{13}{16}$ | 27 | $7\frac{1}{2}$ " $2\frac{1}{8}$ | 40 | 108 | 40 |
| $2\frac{7}{8}$ " $\frac{9}{16}$ | 14 | 4 " $\frac{3}{4}$ | 24 | 7 " $1\frac{7}{8}$ | 36 | 96 | 36 |
| ..... | ..... | $3\frac{3}{4}$ " $\frac{3}{4}$ | 22 | $6\frac{1}{2}$ " $1\frac{5}{8}$ | 32 | 88 | 32 |
| $2\frac{3}{4}$ " $\frac{1}{2}$ | $12\frac{1}{2}$ | $3\frac{1}{2}$ " $\frac{11}{16}$ | 20 | 6 " $1\frac{1}{2}$ | 28 | 80 | 28 |
| ..... | ..... | $3\frac{1}{4}$ " $\frac{5}{8}$ | 18 | $5\frac{3}{4}$ " $1\frac{1}{2}$ | 27 | 72 | 27 |
| 2 " $\frac{5}{8}$ | 10 | 3 " $\frac{5}{8}$ | 16 | $5\frac{1}{2}$ " $1\frac{3}{8}$ | 26 | 64 | 26 |
| $1\frac{1}{8}$ " $\frac{1}{2}$ | 8 | $2\frac{7}{8}$ " $\frac{9}{16}$ | 14 | $5\frac{1}{4}$ " $1\frac{1}{4}$ | 24 | 56 | 24 |
| ..... | ..... | $2\frac{3}{4}$ " $\frac{1}{2}$ | 12 | 5 " $1\frac{1}{4}$ | 22 | 48 | 22 |
| ..... | ..... | 2 " $\frac{5}{8}$ | 10 | 4 " $1\frac{1}{3}$ | 20 | 40 | 20 |
| ..... | ..... | $1\frac{7}{8}$ " $\frac{1}{2}$ | 8 | 3 " 1 | 16 | 32 | 16 |

## TO FIND THE BREAKING STRAIN OF HEMP ROPES.

$$\text{Breaking weight in tons} = \frac{\text{circumference squared in ins.}}{4}$$

*Example.*—What is the breaking weight of a rope 8 inches in circumference ?

$$\frac{8 \times 8}{4} = 16 \text{ tons.}$$

To find the weight which may be safely appended to a hemp rope :

$$W = \frac{\text{circumference squared in inches.}}{10}$$

*Example.*—What weight might be safely appended to a hemp rope 10 inches in circumference ?

$$\frac{10^2}{10} = 10 \text{ tons. Answer.}$$

## TABLE OF THE WEIGHT AND STRENGTH OF CHAIN.

| Diameter. Inches. | Weight per fathom lbs. | Proof strength Tons. | Diameter. Inches. | Weight per fathom lbs. | Proof strength Tons. |
|---|---|---|---|---|---|
| $0\frac{5}{16}$ | $5\frac{1}{2}$ | 1·27 | $1\frac{3}{16}$ | 76 | 29 |
| $0\frac{3}{8}$ | 8 | 1·83 | $1\frac{1}{4}$ | 84 | 32 |
| $0\frac{7}{16}$ | $10\frac{1}{2}$ | 2·5 | $1\frac{5}{16}$ | 93 | 35 |
| $0\frac{1}{2}$ | $13\frac{3}{4}$ | 4 | $1\frac{3}{8}$ | 102 | 38 |
| $0\frac{9}{16}$ | 17 | 5 | $1\frac{7}{16}$ | 111 | 41 |
| $0\frac{5}{8}$ | 22 | 6 | $1\frac{1}{2}$ | 120 | 44 |
| $0\frac{11}{16}$ | 26 | 7·25 | $1\frac{9}{16}$ | 128 | 48 |
| $0\frac{3}{4}$ | 30 | 10 | $1\frac{5}{8}$ | 136 | 52 |
| $0\frac{13}{16}$ | 36 | 11·5 | $1\frac{11}{16}$ | 142 | 56 |
| $0\frac{7}{8}$ | 42 | 13 | $1\frac{3}{4}$ | 148 | 60 |
| $0\frac{15}{16}$ | 49 | 15 | $1\frac{13}{16}$ | 150 | 65 |
| 1 | 55 | 18 | $1\frac{7}{8}$ | 162 | 70 |
| $1\frac{1}{16}$ | 60 | 22 | $1\frac{15}{16}$ | 171 | 75 |
| $1\frac{1}{8}$ | 68 | 26 | 2 | 180 | 80 |

## HOW TO USE WIRE ROPE.

Wire ropes used for hoisting are manufactured with 19 wires to the strand. Those with twelve or seven wires to the strand are stiffer and are best adapted for guys, ferries

and rigging. Wire ropes are made with 6 strands, with a centre of hemp or wire, the former being more pliable, and will wear better over small pulleys and drums. They are made of iron or steel, and sometimes up to three inches in diameter.

In the machinery for wire rope the drums and sheaves should be made as large as possible. Wire rope is as pliable as new hemp rope of the same strength, and can be used on the same sized sheaves and pulleys, but the greater the diameter of the sheaves, pulleys or drums, the longer wire rope is found to wear. It is found that the wear increases with the speed. It is therefore better to increase the load than the speed.

It injures wire rope to coil or uncoil it like hemp rope. All untwisting or kinking should be avoided. When not on a reel, it should be rolled on the ground like a wheel, to prevent kinking. Raw linseed oil applied with a piece of sheepskin, wool inside, will preserve wire rope. The oil can be mixed with equal parts of Spanish brown or lamp black. When the wire is under water or under ground, take mineral or vegetable tar, and add one bushel of fresh slacked lime to one barrel of tar, which will neutralize the acid. Boil well, and add saw-dust to give the mixture body, and then saturate the rope with it.

Steel ropes are, to some extent, taking the place of iron ropes, where lightness combined with strength is required. In substituting a steel rope for an iron running rope, the object in view should be rather to increase the wear than to reduce the size. A safe working load is from one-fifth to one-seventh of the ultimate strength, according to speed. When wire ropes are substituted for hemp ropes, the same weight per foot should be allowed for the former as experience has approved for the latter.

The grooves of cast iron pulleys and sheaves should be filled with well-seasoned blocks of hard wood set on end, to be renewed when worn out. This end wood will save wear and increase adhesion. The smaller pulleys or rollers, which support the ropes on inclined planes, should be constructed on the same plan. When large sheaves run with very great velocity, the grooves should be lined with leather, set on end, or with India rubber. This is done in the case of all sheaves used in the *transmission of power* between distant points by means of rope, which frequently run at the rate of 4,000 feet per minute.

ESTABLISHED 1848.

# THE HAZARD MFG. CO.,

## WILKES-BARRE, PA.,

AND 87 LIBERTY STREET, NEW YORK.

## Manufacturers of Steel and Iron, Flat and Round

# WIRE ROPE,

BRIDGE CABLES, SHIP RIGGING, WHEELS AND ROPES FOR TRANSMISSION OF POWER, GALVANIZED TELEGRAPH WIRE, &c.

To meet the large and increasing demand for our Wire Ropes, we have recently completed our new factory at Wilkes-Barre, Penn'a, with improved machinery and greatly enlarged capacity, and are now prepared to manufacture and supply, at short notice, *Wire Ropes of Steel and Iron*, for use on Elevators, Planes, Shafts, Bridges, Ferries, Ship Rigging, and for transmission of power. Our ropes are made of the best brands of Swedes and Norway Charcoal Iron, and superior quality of Steel, the wire being drawn at our own factory. These works were established in 1848, and their production has steadily increased. We now have machinery which is not equalled in the world, for capacity to make large flat or round ropes, enabling us to manufacture a rope of *any size*, and up to *sixty tons* weight, in *one continuous piece, without splicing either the strands or rope*. Our ropes are in general use by the large Mining, Railroad and Canal Companies in Pennsylvania and other States, and their superiority is unquestioned.

We keep constantly on hand, both at our Factory and Warehouse, No. 87 Liberty street, New York, all sizes of Ropes, and will cut any length to order at short notice.

All sizes of Shackles, Sockets, Swivel Hooks, furnished when required, securely put on, and ropes spliced.

For prices, instructions on the use of Wire Ropes, and other information, address

## THE HAZARD MANUFACTURING CO.,

WILKES-BARRE, Pa.,

or, 87 Liberty St., New York.

# GALVANIZED IRON WIRE ROPE FOR SHIPS' RIGGING AND GUYS FOR DERRICKS.

MANUFACTURED BY THE HAZARD MANUFACTURING COMPANY, WILKES-BARRE, PA.

| CHARCOAL ROPE. | | | | GALVANIZED WIRE ROPE THIMBLES. | |
|---|---|---|---|---|---|
| Circumfer'e in inches. | Weight per fathom in pounds. | Circumf'e of Hemp Rope of equal strength. | Breaking strain in tons of 2,000 pounds. | Width of Score. Inches. | Circumference of Rope. Inches. |
| 5½ | 26½ | 11 | 43 | ¼ | ¾ |
| 5¼ | 24½ | 10½ | 40 | ⅜ | 1 |
| 5 | 22 | 10 | 35 | ½ | 1½ |
| 4¾ | 20½ | 9½ | 33 | ⅝ | 2 |
| 4½ | 18 | 9 | 30 | ¾ | 2½ |
| 4¼ | 16 | 8½ | 26 | ⅞ | 2¾ |
| 4 | 14¾ | 8 | 23 | 1 | 3 |
| 3¾ | 12 | 7½ | 20 | 1⅛ | 3½ |
| 3½ | 10¾ | 7 | 16 | 1¼ | 3¾ |
| 3¼ | 9½ | 6½ | 14 | 1⅜ | 4 |
| 3 | 8 | 6 | 12 | 1½ | 4½ |
| 2¾ | 6¾ | 5½ | 10 | 1⅝ | 5 |
| 2½ | 5½ | 5 | 9 | ..... | ..... |
| 2¼ | 4¼ | 4½ | 8 | ..... | ..... |
| 2 | 3½ | 4 | 7 | ..... | ..... |
| 1¾ | 2½ | 3½ | 5 | ..... | ..... |
| 1½ | 2 | 3 | 3½ | ..... | ..... |
| 1¼ | 1½ | 2½ | 2½ | ..... | ..... |
| 1 | ¾ | 2 | 2 | ..... | ..... |
| ⅞ | ½ | 1½ | 1 | ..... | ..... |

Parties in ordering should state for what purpose the rope is to be used, and also state the kind of centre wanted, whether hemp or wire, and advice will be given.

Correspondence solicited, and estimates cheerfully given.

## THE HAZARD MANUFACTURING CO.,

WILKES-BARRE, Pa.,

or, 87 Liberty St., New York.

# STANDARD HOISTING ROPES WITH 19 WIRES TO THE STRAND.

MANUFACTURED BY THE HAZARD MANUFACTURING COMPANY.

## IRON.

| Trade No. | Circumference in inches. | Diameter. | Weight per ft. in lbs. of Rope with Hemp Cen. | Breaking strain in tons of 2,000 pounds. | Proper working load in tons of 2,000 pounds. | Circumference of Hemp Rope of equal strength. | Min. size of drum or sheave in ft. |
|---|---|---|---|---|---|---|---|
| 1 | 6¾ | 2¼ | 8 00 | 74 | 15 | 15½ | 8 |
| 2 | 6 | 2 | 6.30 | 6 | 13 | 14½ | 7 |
| 3 | 5½ | 1¾ | 5.25 | 54 | 11 | 13 | 6½ |
| 4 | 5 | 1⅝ | 4.10 | 44 | 9 | 12 | 5 |
| 5 | 4¾ | 1½ | 3.65 | 39 | 8 | 11½ | 4½ |
| 6 | 4 | 1¼ | 2.50 | 27 | 5½ | 9½ | 4 |
| 7 | 3½ | 1⅛ | 2.00 | 20 | 4 | 8 | 3½ |
| 8 | 3⅛ | 1 | 1.58 | 16 | 3 | 7 | 3 |
| 9 | 2¾ | ⅞ | 1.20 | 11½ | 2½ | 6 | 2¾ |
| 10 | 2¼ | ¾ | 0.88 | 8.64 | 1¾ | 5 | 2½ |
| 10¼ | 2 | ⅝ | 0.70 | 5.13 | 1¼ | 4½ | 2 |
| 10½ | 1⅝ | 9/16 | 0.44 | 4.27 | ¾ | 4 | 1¾ |
| 10¾ | 1½ | ½ | 0.35 | 3.48 | ½ | 3½ | 1½ |

## CAST STEEL.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 6¾ | 2¼ | 8.00 | 130 | 26 | | 9 |
| 2 | 6 | 2 | 6.30 | 100 | 21 | | 8 |
| 3 | 5½ | 1¾ | 5.25 | 78 | 17 | 15¾ | 7½ |
| 4 | 5 | 1⅝ | 4.10 | 64 | 13 | 14½ | 6 |
| 5 | 4¾ | 1½ | 3.65 | 55 | 11 | 13½ | 5½ |
| 6 | 4 | 1¼ | 2.50 | 39 | 8 | 11½ | 5 |
| 7 | 3½ | 1⅛ | 2.00 | 30 | 6 | 10 | 4½ |
| 8 | 3⅛ | 1 | 1.58 | 24 | 5 | 9¼ | 4 |
| 9 | 2¾ | ⅞ | 1.20 | 20 | 4 | 8 | 3¾ |
| 10 | 2¼ | ¾ | 0.88 | 13 | 3 | 6½ | 3½ |
| 10¼ | 2 | ⅝ | 0.70 | 9 | 2 | 5¼ | 3 |
| 10½ | 1⅝ | 9/16 | 0.44 | 6½ | 1½ | 4¾ | 2¾ |
| 10¾ | 1½ | ½ | 0.35 | 5½ | 1 | 4½ | 2 |

NOTE.—The weight of Wire Centre Ropes is 10 per cent. more than that of Ropes with Hemp Centres.

# TRANSMISSION AND STANDING ROPES WITH 7 WIRES TO THE STRAND.

MANUFACTURED BY THE HAZARD MANUFACTURING COMPANY.

## IRON.

| Trade No. | Circumference | Diameter. | Weight per ft. in lbs. of Rope with Hemp Cen. | Breaking strain in tons of 2,000 pounds. | Proper working load in tons of 2,000 pounds. | Circumference of Hemp Rope of equal strength. |
|---|---|---|---|---|---|---|
| 11 | 4 5/8 | 1 1/2 | 3.37 | 36 | 9 | 10 3/4 |
| 12 | 4 1/4 | 1 3/8 | 2.77 | 30 | 7 1/2 | 10 |
| 13 | 3 3/4 | 1 1/4 | 2.28 | 25 | 6 1/4 | 9 1/4 |
| 14 | 3 3/8 | 1 1/8 | 1.82 | 20 | 5 | 8 |
| 15 | 3 | 1 | 1.50 | 16 | 4 | 7 |
| 16 | 2 5/8 | 7/8 | 1.12 | 12.3 | 3 | 6 1/4 |
| 17 | 2 3/8 | 3/4 | 0.88 | 8.8 | 2 1/4 | 5 1/4 |
| 18 | 2 1/8 | 11/16 | 0.70 | 7.6 | 2 | 5 |
| 19 | 1 7/8 | 5/8 | 0.57 | 5.8 | 1 1/2 | 4 3/4 |
| 20 | 1 5/8 | 9/16 | 0.41 | 4.1 | 1 | 4 |
| 21 | 1 3/8 | 1/2 | 0.31 | 2.83 | 3/4 | 3 1/4 |
| 22 | 1 1/4 | 7/16 | 0.23 | 2.13 | 1/2 | 2 3/4 |
| 23 | 1 1/8 | 3/8 | 0.19 | 1.65 | ..... | 2 1/2 |
| 24 | 1 | 5/16 | 0.16 | 1.38 | ..... | 2 1/4 |
| 25 | 7/8 | 9/32 | 0.125 | 1.03 | ..... | 2 |

## CAST STEEL.

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 4 5/8 | 1 1/2 | 3.37 | 67 | 16 | 15 |
| 12 | 4 1/4 | 1 3/8 | 2.77 | 55 | 12 1/2 | 13 |
| 13 | 3 3/4 | 1 1/4 | 2.28 | 45 | 10 | 12 |
| 14 | 3 3/8 | 1 1/8 | 1.82 | 36 | 8 | 10 3/4 |
| 15 | 3 | 1 | 1.50 | 30 | 6 1/2 | 10 |
| 16 | 2 5/8 | 7/8 | 1.12 | 22 | 5 | 8 1/2 |
| 17 | 2 3/8 | 3/4 | 0.88 | 17 | 3 1/2 | 7 1/4 |
| 18 | 2 1/8 | 11/16 | 0.70 | 13 1/2 | 3 | 6 1/2 |
| 19 | 1 7/8 | 5/8 | 0.57 | 10 | 2 1/4 | 5 1/2 |
| 20 | 1 5/8 | 9/16 | 0.41 | 8 | 1 3/4 | 5 |
| 21 | 1 3/8 | 1/2 | 0.31 | 6 | 1 1/4 | 4 3/4 |
| 23 | 1 1/8 | 3/8 | 0.19 | 4 | 1 | 3 3/4 |
| 24 | 1 | 5/16 | 0.16 | 3 | 3/4 | 3 1/4 |

## SPLICING WIRE ROPE. (*Hallidie.*)

About 84 feet of rope is required to put in a good, smooth, long splice. The wire ropes employed in these ropeways are made six strands of seven wires each, and a core or heart; as there are two rope ends to splice together, there will consequently be twelve strands to be tucked in. Operators usually tie the stops that mark the length of rope, about where the centre of the splice will be. In this case the usual way is to unlay each rope up to that point, and place the strands of rope A between the strands of rope B, the core or hearts of the ropes A and B being cut off so that the cores of the ropes abut against each other. There will be then 42 ft. of strands each side of the stop, as is shown in Fig. 1

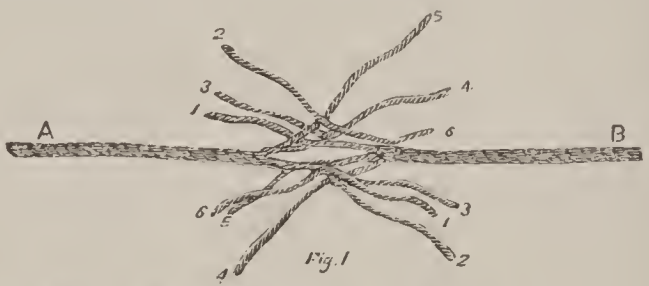


Fig. 1

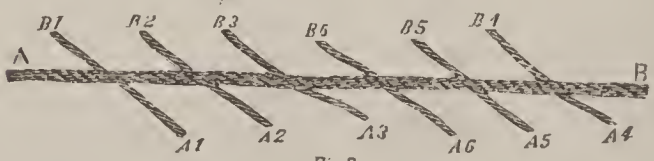


Fig. 2.

Fig 3d

It is important that each strand should be in its proper place, so that none of them cross other strands, or that two strands be not where one strand should be (by placing your fingers between each other in natural position, this will be understood). Then strand No 1 of rope A is unlaid, and strand No. 1 of rope B follows close, and is laid snugly and tightly without a kink or bend in its place, until within seven feet of the end; a temporary seizing is then put on securing ropes and strands at this point. Strand No. 1 of rope A is then cut off, leaving it seven feet long. Then strand No. 2 of rope A is unlaid, and strand 3 of rope B is laid in its place to within twenty-one feet of its end. Strand No. 3 of rope A is unlaid, and strand No. 3 of rope B is lain in its place, within thirty-

five feet of end. By this time you have reached within seven feet of the centre, and reversing the operation, unlay strand No. 4 of rope B, and lay in its place strand No. 4 of rope A, to within seven feet of its end; unlay No. 5 of rope B, and lay in No. 5 of rope A, to within twenty-one feet of its end; finally, unlay No. 6 of rope B, and lay in its place No. 6 of rope A, to within thirty-five feet of its end. The strands are now all laid in their places and seized down for the time being, the ends are cut off, as with the first strand, to seven feet in length, and present the appearance as in Fig. 2.

The next operation is to tuck the ends, and we will proceed to tuck in B 1. It will be remembered that the ropes are made of six strands, laid around a core or heart, usually of hemp, of the same size. Two clamps (Fig. 3) made for this purpose are fastened on the rope so as to enable the operator to untwist the rope sufficiently to open the strands and permit the core to be taken out (see diagram), which is cut away, leaving a space in the centre of the rope; the strand B 1 is placed across A 1, and put in the centre of the rope in place of the extracted core, forming in fact a new core. A flat-nosed T-shaped needle used in splicing, the point of which is about one-half inch wide by three-sixteenths of an inch thick, rounded off to an edge, is well adapted to this purpose. The strand B 1 is laid in its entire length, the core being cut off exactly at the extremity of strand B 1, so that when the rope is enclosed around the inserted strand, the ends of the strand and core should abut. If there is much space left in the centre of the rope without a core, the rope is liable to lose its proper form and some of the strands fall in, exposing the projecting strands to undue wear. The same operation is performed with A 1, running the other way of the rope, and so on until all the strands are tucked in, which, if properly done, will leave the rope as true and round and as strong as any other part.

Other operators prefer to start from the end of one rope and consequent end of splice. The operation is about the same, but the experience of the writer justifies him in saying that more care has to be used in bringing all the strands to an even tension in the parts spliced. Other variations in detail are made according to the fancy or practice of the splicer, but after making a few successful splices in manner above described, the operator can afterward vary to suit himself.

## TO FIND THE ULTIMATE TRANSVERSE STRENGTH OF BEAMS.

1.—Beam supported at both ends, and loaded in middle:

Let L = length in inches.
B = breadth "
D = depth "
W = breaking weight in lbs.

M = { 1672 for English Oak.
1556 " beech.
1013 " elm.
1632 " pitch pine.
1341 " red pine.
900 " larch.
9000 " wrought iron.
6000 " cast iron. }

$$W = \frac{D^2 \times B \times 4 \times M}{L}; \text{ or } W = \frac{4\,D \times B \times D \times M}{L}$$

These rules show how to find the weight that will BREAK the beams ; when the weight that may be safely placed upon them is not more than one-third for a steady, or one-sixth for a moving or suddenly applied load ; and in the case of timber, beams that have to bear a permanent load should not be more than one-tenth, in order to allow for the effect of decay.

---

## STRENGTH OF ROLLED IRON BEAMS.

B W = Breaking weight distributed in tons.

| Depth of Beam. Inches. | Size of flange. In. In. | B. W. FOR DIFFERENT SPANS. 10 ft. | 15 ft. | 20 ft. | 25 ft. |
|---|---|---|---|---|---|
| 5 | 2 × ½ | 6.6 | — | — | — |
| 6 | 2½ × ½ | 10 | 6.6 | 5 | — |
| 7 | 3 × ½ | 14 | 9 | 7 | 5 |
| 8 | 3 × ⅝ | 20 | 13 | 10 | 8 |
| 9 | 4 × ¾ | 36 | 24 | 18 | 14 |
| 10 | 4½ × 1 | 60 | 40 | 30 | 24 |

## STRENGTH OF COLUMNS.

TABLE OF PRACTICAL FORMULA BY WHICH TO DETERMINE THE AMOUNT OF WEIGHT A COLUMN OF GIVEN DIMENSIONS WILL SUPPORT, IN POUNDS.

For a rectangular column of cast iron.....$W = \frac{15300\, l\, b^3}{4\, b^2 + .18\, l^2}$

For a rectangular col. of malleable iron, $W = \frac{17800\, l\, b^3}{4\, b^2 + .16\, l^2}$

For a rectangular column of oak.....$W = \frac{3960\, l\, b^3}{4\, b^2 + 5\, l^2}$

For a solid cylinder of cast iron.....$W = \frac{9562\, d^4}{4\, d^2 + .18\, l^2}$

For a solid cylinder of malleable iron.....$W = \frac{11125\, d^4}{4\, d^2 + .16\, l^2}$

For a solid cylinder of oak.....$W = \frac{2470\, d^4}{4\, d^2 + .5\, l^2}$

NOTE.—W = the weight the column will support in lbs.; $b$ = the breadth in inches; $l$ = the length in feet; $d$ = the diameter in inches.

---

## APPROXIMATE RULE FOR THE STRENGTH OF RECTANGULAR PILLARS OF WOOD.

(*Molesworth.*)

L = Length of pillar.
B = Breadth of ditto.
W = Crushing weight in lbs. per square inch of section.

Safe load per square inch of sectional area = $\frac{W}{10}$.

| Material. | Values of W when L. or Length = | | | | |
|---|---|---|---|---|---|
| | 8 B. | 12 B. | 24 B. | 36 B. | 48 B. |
| Oak ..... | 5500 | 4600 | 2700 | 1800 | 900 |
| Ash ..... | 6000 | 5000 | 3000 | 2000 | 1000 |
| Red pine.... | 4800 | 4000 | 2400 | 1600 | 800 |

## RELATIVE STRENGTH OF MATERIALS IN LONG COLUMNS.

| | |
|---|---|
| Cast Iron being assumed as | = 1000 |
| Wrought Iron | = 1745 |
| Cast Steel | = 2518 |
| Oak | = 109 |
| Red Deal | = $78\frac{1}{2}$ |

---

## RELATIVE STRENGTH OF ROUND AND FLAT ENDS IN LONG COLUMNS.

| | |
|---|---|
| Both ends rounded, 1 strength | = 1 |
| One end flat and firmly fixed, 1 strength | = 2 |
| Both ends flat and firmly fixed | = 3 |

---

## RELATIVE STRENGTH OF SECTION IN LONG SOLID COLUMNS.

| | |
|---|---|
| Cylindrical | 100 |
| Triangular | 110 |
| Square | 93 |

---

## HOLLOW COLUMNS.

The strength nearly equals the difference between that of two solid columns, the diameters of which are equal to the external and internal diameters of the hollow one.

---

## RELATIVE BREAKING WEIGHT PER SQUARE INCH OF WROUGHT AND CAST IRON PILLARS.

| | | Wrought. Tons. | Cast. Tons. |
|---|---|---|---|
| Ratio of least thickness to height | $\frac{1}{10}$ | 15.5 | 28.6 |
| " " " | $\frac{1}{20}$ | 14.2 | 17.9 |
| " " " | $\frac{1}{26 \cdot 4}$ | 13.0 | 13.0 |
| " " " | $\frac{1}{30}$ | 12.4 | 11.0 |
| " " " | $\frac{1}{40}$ | 10.5 | 7.1 |

# SAFE LOAD FOR HOLLOW CAST IRON PILLARS.

| Thickness of metal. | External diameter. Inches. | LENGTH OF PILLAR 8 ft. Tons. | 10 ft. Tons. | 12 ft. Tons. | 14 ft. Tons. | 16 ft. Tons. |
|---|---|---|---|---|---|---|
| ½ in. | 3 | 4.0 | 3.2 | 2.3 | 1.8 | 1.4 |
| | 3½ | 5.9 | 5.1 | 3.6 | 2.7 | 2.3 |
| | 4 | 8.1 | 6.1 | 4.7 | 3.6 | 3.4 |
| | 4½ | 10.6 | 8.1 | 6.5 | 5.0 | 4.4 |
| | 5 | 13.3 | 10.4 | 8.3 | 6.7 | 5.4 |
| | 5½ | 15.3 | 12.9 | 10.5 | 8.5 | 7.0 |
| | 6 | 19.0 | 15.5 | 12.7 | 9.5 | 8.7 |
| ⅝ in. | 3 | 4.7 | 3.5 | 2.6 | 2.0 | 1.6 |
| | 3½ | 7.1 | 5.3 | 4.2 | 3.2 | 2.5 |
| | 4 | 9.2 | 7.3 | 5.6 | 4.4 | 3.9 |
| | 4½ | 12.8 | 9.9 | 7.7 | 6.1 | 5.5 |
| | 5 | 16.1 | 12.7 | 9.1 | 8.1 | 7.0 |
| | 5½ | 18.7 | 15.7 | 12.8 | 10.4 | 8.8 |
| | 6 | 23.2 | 19.0 | 15.6 | 12.8 | 10.6 |
| | 6½ | 86.9 | 22.4 | 18.7 | 15.2 | 13.0 |
| | 7 | 30.7 | 26.0 | 21.9 | 18.5 | 15.6 |
| ¾ in | 3 | 5.4 | 3.8 | 2.8 | 2.2 | 1.7 |
| | 3½ | 8.1 | 6.2 | 4.4 | 3.5 | 2.6 |
| | 4 | 11.3 | 8.5 | 6.5 | 4.8 | 3.8 |
| | 4½ | 14.9 | 11.5 | 8.9 | 7.2 | 6.0 |
| | 5 | 18.8 | 14.8 | 11.7 | 9.0 | 7.7 |
| | 5½ | 21.8 | 18.4 | 14.9 | 12.1 | 10.2 |
| | 6 | 27.2 | 22.3 | 18.3 | 15.0 | 12.5 |
| | 6½ | 31.6 | 26.3 | 21.9 | 17.8 | 15.3 |
| | 7 | 36.1 | 30.6 | 25.8 | 21.7 | 18.4 |
| 1 in. | 4 | 13.9 | 10.4 | 8.0 | 6.4 | 4.8 |
| | 4½ | 18.5 | 14.3 | 11.1 | 8.8 | 7.1 |
| | 5 | 23.6 | 18.6 | 14.8 | 11.9 | 9.6 |
| | 5½ | 27.6 | 23.2 | 18.9 | 15.3 | 12.7 |
| | 6 | 34.5 | 28.3 | 23.2 | 19.1 | 15.9 |
| | 6½ | 40.3 | 33.6 | 28.0 | 22.8 | 19.6 |
| | 7 | 46.2 | 39.1 | 33.0 | 27.8 | 23.6 |
| | 7½ | 52.2 | 44.9 | 38.3 | 32.6 | 27.9 |
| | 8 | 58.3 | 50.7 | 43.8 | 37.7 | 32.5 |
| | 8½ | 64.3 | 56.5 | 49.4 | 42.9 | 37.3 |
| | 9 | 70.5 | 62.7 | 55.3 | 48.1 | 42.3 |

## TABLE OF THE RESISTANCE OF MATERIALS TO BREAKING ACROSS.

IN POUNDS AVOIRDUPOIS PER SQUARE INCH.

(*Rankine.*)

NOTE.—The modulus of rupture is eighteen times the load which is required to break a bar of one inch square, supported at two points one foot apart, and loaded in the middle between the points of support.

| Materials. | Resistance to breaking or modulus of rupture. |
|---|---|
| Sandstone | 1,100 to 2,360 |
| Slate | 5,000 |
| Iron, cast, open-work beams, average | 17,000 |
| Iron, cast, solid | 40,000 |
| Ash | 12,000 to 14,000 |
| Beech | 9,000 to 12,000 |
| Birch | 11,700 |
| Elm | 6,000 to 9,700 |
| Red Pine | 7,100 to 9,540 |
| Spruce | 9,900 to 12,300 |
| Lignum Vitæ | 12,000 |
| Oak, British and Russian | 10,000 to 13,600 |
| " Dantzic | 8,700 |
| " American Red | 10,600 |
| Sycamore | 9,600 |

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## GREATEST SAFE LOAD, PER SUPERFICIAL FOOT.

| | |
|---|---|
| On Granite piers is | 40 tons. |
| Portland stone piers | 13 " |
| Bath stone piers | 8 " |
| Brickwork in cement | 3 " |
| Rubble masonry | 2 " |
| Lime concrete foundation | $2\frac{1}{2}$ " |

[The height of brick or stone piers should never exceed 12 times their least thickness at base.]

## NOTES ON STRENGTH OF MATERIALS.

(*From Molesworth.*)

Wet timber is not so strong as dry ; in some cases it is not half the strength of dry.

Cold-blast iron is stronger than hot-blast.

Annealing cast-iron diminishes its tensile strength.

Re-melting (up to ten or twelve meltings) or prolonged fusion, increases the strength and density of cast iron. Softer irons will best bear re-melting.

Indirect strains reduce the tensile strength of cast iron.

Additional strength should be given to cast iron girders that take the load on one side of the bottom flange.

The tenacity of cast iron is only one-third that of wrought iron, and should not be subjected to more than one-sixth of the breaking strain.

Tensile strain on wrought iron should not exceed one-fourth of the breaking weight.

Annealing iron wire diminishes its strength.

High temperature in casting is injurious to gun-metal.

Plated webs are more economical than braced webs in shallow girders, or near the ends of long girders. In small lattice girders it is better to make the lattices uniform throughout.

# MACHINERY, &c.

## SHAFTING.

Shafts are subject to two forces—transverse strain and torsion.

When the machines to be driven are below the shaft, there is a transverse strain on the shaft, due to the weight of the shaft itself, of the pulley and tension of the belt. Sometimes the power is taken off horizontally on one side, in which case the tension of the belt produces a horizontal transverse strain, while the weight of the pulley acts with the weight of the shaft to produce a vertical transverse strain. When the machinery to be driven is placed on the floor above the shaft, the tension of the belt produces a transverse strain in opposite direction to that due to the weight of the shaft and pulley. The transverse strain diminishes as the velocity of the shaft increases.

The torsional strength of shafts or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness or resistance to bending is proportional to the fourth power of their diameters, and varies inversely in proportion to their load and also to the cube of the length of their spans.

## STRENGTH OF WROUGHT IRON SHAFTING.

D = Diameter of shaft in inches.
H = Indicated horse-power to be transmitted.
N = Number of revolutions per minute.

$$D = \sqrt[3]{\frac{83\,H}{N}}; \qquad H = \frac{D^3\,N}{83}$$

in crank shafts and prime movers.

$$D = \sqrt[3]{\frac{65\,H}{N}}; \qquad H = \frac{D^3\,N}{83}$$

for ordinary shafting.

## CO-EFFICIENTS OF FRICTION IN AXLES.

| Axle. | Bearing. | Dry. | Greasy and Wet. | Ordinary Lubrication. | Lubricated Continuously. | Lard and Plumbago. | Fatty Matter. |
|---|---|---|---|---|---|---|---|
| Bell Metal. | Bell Metal, | ..... | ..... | ·097 | ..... | ..... | ..... |
| Cast Iron. | " " | ..... | ..... | ..... | ·049 | ..... | ..... |
| Wrought Iron. | " " | 25 | ·19 | ·07 | ·05 | ·11 | ..... |
| " " | Cast Iron. | ..... | ..... | 07 | ·05 | ..... | ..... |
| Cast Iron. | " " | ..... | ·13 | ·07 | ·05 | ..... | ·14 |
| " " | Bell Metal. | ·19 | ·16 | ·07 | ·05 | ..... | ·16 |
| Wrought Iron. | Lignum Vitæ. | ·19 | ..... | ·12 | ..... | ..... | ..... |
| Cast Iron. | " " | ·18 | ..... | ·10 | ·09 | ·11 | ·14 |
| Lignum Vitæ. | Cast Iron. | ..... | ..... | ·11 | ..... | ..... | ·15 |
| " " | Lignum Vitæ. | ..... | ..... | ..... | ·07 | ..... | ..... |

## FRICTIONAL RESISTANCE OF SHAFTING.

(*Webber.*)

K = Co-efficient of friction.
W = Work absorbed in foot-pounds.
P = Weight of shafting and pulleys + resultant stress on belts.
H = Horse-power absorbed.
D = Diameter of journals in inches.
R = Number of revolutions per minute.

In ordinary oiling

$W = .0182\ P\ D.$
$H = .000000556\ P\ D\ R.$
$K = .066.$

In continuous oiling

$W = .0112\ P\ D.$
$H = .000000339\ D\ P\ R.$
$K = .044.$

As a rough approximation, 100 feet of shafting, 3 inches diameter, making 120 revolutions per minute, requires 1 horse-power.

Pressure on bearings should not exceed 750 pounds per square inch, measured axially.

Cast iron bearings wear well if the pressure does not exceed 100 pounds per square inch, or velocity 150 feet per minute.

## STRENGTH OF SHAFTING TO RESIST TORSION.

L = Length of lever in inches, or radius of wheel at which force is applied.
F = Force applied in pounds.
D = Diameter of shaft in inches.
K = 1700 for wrought iron; 3200 for cast steel; 1500 for cast iron.

$$D = \sqrt[3]{\frac{F\ L}{K}}\ ; \qquad F = \frac{D^3\ K}{L}$$

*Example.*—Required to find the diameter of a wrought iron shaft for a drum having 2 tons pulling on it at 30 inch radius. L = 30; F = 2 × 2240 = 4480; K = 1700; then

$$D = \sqrt[3]{\frac{30 \times 4480}{1700}} = 4.3 \text{ inches.}$$

---

## BELTING AND VELOCITY OF PULLEYS.

Belts should not be made tighter than necessary. Over half the trouble from broken pulleys, hot boxes, &c., can be traced to the fault of tight belts, while the machinery wears much more rapidly than when loose belts are employed.

The speed of belts should not be more than 3000 or 3750 feet per minute.

The motion of driving should run with and not against the laps of the belts.

Leather belts should be run with the strongest or flesh side on the outside and the grain (hair) side on the inside, nearest the pulley, so that the strongest part of the belt may be subject to the least wear. It will also drive 30 per cent. more than if run with the flesh side nearest the pulley. The grain side adheres best because it is smooth. Do not expose leather belts to the weather.

When the length of a belt cannot be conveniently ascertained by measuring around the pulleys with a tape line, the following rule will be serviceable :

Add the diameters of the two pulleys together and divide by 2; multiply this quotient by $3\frac{1}{4}$, and to the product add twice the distance between the centres of the shafts; the sum will be the length required.

The transmitting power of a double belt is to that of a single belt as 10 is to 7. In ordering pulleys the kind of belt to be used should always be specified.

The safe working tension of a belt is assumed to be 45 pounds per inch of width, which is equal to a velocity of about 60 square feet per minute per horse-power.

To find the horse-power a single belt can transmit, the size of the pulley and the width of the belt being given: Let

C = Circumference in inches of pulley.
D = Diameter.
R = Revolutions per minute.
W = Width of belt in inches.
H = Horse-power that can be transmitted by the belt.

$$H = \frac{C\ R\ W}{8640} \quad \text{or } H = \frac{D\ R\ W}{2750}$$

To find the width of belt required when the horse-power to be transmitted and the size of the pulley are given:

$$W = \frac{H \times 2750}{D\ R}$$

The horse-power and width of belt being given, to find the diameter of pulley:

$$D = \frac{H \times 2750}{R\ W}$$

The horse-power, diameter of pulley and width of belt being given, to find the number of revolutions necessary:

$$R = \frac{H \times 2750}{D\ W}$$

The above rules are only applicable when the pulleys are of equal diameters. When they are of unequal diameters so that the points of contact are unequal, these rules must be modified accordingly.

V = Velocity of belt in feet per minute.
H = Horse-power transmitted by belt.
W = Width of single belting.

$$x = \frac{33000 \times H}{V}$$

S = Strain on belting in lbs. = x + k x
k = 1.1 when arc of belt contact of driven pulley = .40 of circumference; .77 when arc of contact = .50 circumference; .62 when arc of contact = .60 circumference.
W = .02 × S

An approximate rule for single belting is:

$$W = \frac{1100 \times H}{V}$$

$$V = \frac{1100 \times H}{W}$$

$$H = \frac{W\ V}{1100}$$

To find the velocity of the driven pulley when the diameter of the driver is given:

D = Diameter of driver.
d = Diameter of driven.
R = Number of revolutions of driver.
r = Number of revolutions of driven.

$$r = \frac{D\ R}{d}$$

To find the size of a small pulley when the speed is given:

$$d = \frac{D\ R}{r}$$

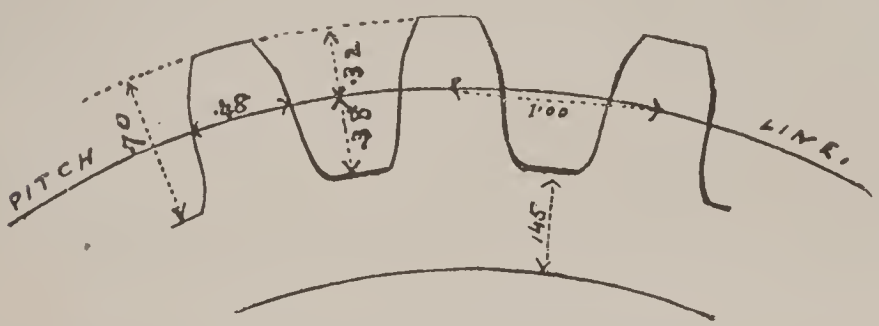
In a train of pulleys the final velocity is =

$$r = \frac{R \times D \times D' \times D''}{d \times d' \times d''}$$

That is, multiply the number of revolutions per minute of the first driver, its diameter and the diameters of all the driving pulleys together; multiply also the diameters of all the driven pulleys together and divide the product of the driven pulleys into the product of the drivers; the quotient will be the speed of the last driven pulley in revolutions per minute.

## TEETHED WHEELS.

All-teethed wheels have what is called a pitch line, which may be said to be the line of contact, if the wheels were reduced to plain cylindrical wheels. If teethed wheels worked close against one another, this pitch line would naturally be the line running through the centre of the teeth parallel to the circumference, but as there is always a little play given to the teeth, the pitch line forms itself a little further towards the outside of the wheel. It is usually about $\frac{14}{25}$ or nearly $\frac{3}{5}$ of the length of the teeth from the bottom to the top of the tooth. The pitch is the distance from centre to centre of two teeth on the pitch line. The pitch is found by dividing the length of a tooth by .70 or the thickness by .48. To find the length of a tooth multiply the pitch by .70, and to find the thickness multiply by .48. The width of teeth in small pitches is generally twice the pitch and in large three times the pitch.




To calculate the strength of teeth, let

B = Breadth of teeth in inches.
P = Pitch of teeth in inches.
V = Velocity of pitch line in feet per second.
H = Horse-power which may be transmitted.

$$H = .06\ P^2\ V\ B$$

$$P = \sqrt{\frac{H}{.06\ V\ B}}$$

$$V = \frac{H}{.06\ P^2\ B}$$

$$B = \frac{H}{.06\ P^2\ V}$$

*Example.*—What is the power of a wheel, the teeth of which are 6 in. wide, 1.35 in. thick, and 2.25 in. long, revolving at the rate of 3 feet per second ?

When the teeth are 2.25 in. long, the pitch is $2.25 \div .75 = 3$, and the square of the pitch is $3 \times 3 = 9$; then $.06 \times 9 \times 3 \times 6 = 9.72$ horse-power.

---

## WORK.

According to Morin, a man laboring ten hours a day will perform the following units of work:

| | |
|---|---|
| Raising material with a wheelbarrow on ramps | 72 |
| Throwing earth to a height of five feet | 470 |

A man laboring eight hours a day:

| | |
|---|---|
| Raising his own body | 4250 |
| Drawing or pushing horizontally | 3120 |
| Pushing and drawing alternately in a vertical direction | 2380 |
| Turning a handle | 2600 |
| Working with his arms and legs as in rowing | 4000 |

A man laboring six hours a day:

| | |
|---|---|
| Raising material with a pulley | 1560 |
| Raising material with the hands | 1470 |
| Raising material upon the back and returning empty | 1126 |

---

## WORK OF ANIMALS.

| | |
|---|---|
| A horse, in a common pumping engine | 17,550 |
| A mule, ditto | 11,700 |

The following memoranda are by the author of a "Glossary of Terms used in the Coal Trade of Northumberland and Durham :"

The average day's work of a young barrowman from 17 to 21 years of age, when putting alone and working 12 hours a day on level road, laid with bridge rails, and with tubs having flanged wheels, 10 in. diameter, is equal to:

| | lbs. pushed one foot. |
|---|---|
| 1 empty tub = 3 cwt. pushed 8280 yards = | 8,346,240 |
| 1 full tub = 10 cwt. pushed 8280 yards = | 27,820,800 |
| Total day's work = | 36,167,040 |

And taking friction at $\frac{1}{6}\frac{1}{5}$ part, the mean permanent force exercised by the barrowman for 12 hours is equal to 556,416 lbs. raised 1 foot in 12 hours, or 773 lbs. raised 1 foot in one minute.

Mr. Nicholas Wood, in a paper read before the North of England Institute of Mining Engineers, said the useful work performed by horses at several North of England collieries averaged 31.93 tons conveyed by each horse one mile per day. At two collieries on a wagon way above ground, it averaged 116.66 tons, and in several collieries in South Wales 13.476 tons. He concluded that a horse was capable of exerting a force of 120 lbs. while traveling at the rate of two and three miles an hour, and that he was capable of continuing that exertion for ten hours.

## SPECIFIC GRAVITY, WEIGHT AND PROPERTIES OF MATERIALS, &c.

The specific gravity of a body is its weight in proportion to an equal bulk of pure water, at a standard temperature The standard temperature is 62° Fahr. = 16.670 Cent. A cubic inch of water weighs 252.456 troy grains, the temperature being 62° Fahr., and the height of the barometrical column 30 inches ; and 7,000 troy grains are equivalent to one pound avoirdupois. Thence it follows that a cubic foot of water would weigh 997,136 ounces.

To find the specific gravity of a *solid heavier than water:* Weigh the body both in air and in water ; to the weight in air annex 3 ciphers, and divide by the difference of weight.

To find the specific gravity of a *solid lighter than water:* Attach to it another body heavy enough to sink it, weigh severally the compound mass, and the heavier body in air and water, and say : As the difference of weights lost in water is to the weight of the given body in air, so is the specific gravity of water to that of the given body.

To find the specific gravity of a *fluid:* Weigh both in and out of the fluid a solid (insoluble) of known specific gravity ; then say : As the weight of the solid to that lost in the fluid, so is the specific gravity of the former to that of the latter.

The weight of a cubic foot of water at a temperature of 60° is 1000 ounces avoirdupois, and the specific gravity of a body, water being 1000, shows the weight of a cubic foot of that body in ounces avoirdupois. Then, if the magnitude of the body be known, its weight can be computed, or if its weight be known, its magnitute can be calculated, provided we know its specific gravity, or of the magnitude, weight and specific gravity, any two being known, the third may be found.

*To find the magnitude of a body from its weight :* Say, as the specific gravity is to its weight in ounces, so is one cubic foot to its magnitude in feet.

*To find the weight of a body from its magnitude:* Say, as one cubic foot is to its magnitude in feet, so is its specfic gravity to its weight in ounces.

# THE WEIGHT OF DIFFERENT SUBSTANCES.

| Name of Body. | Weight of a cubic foot. | | Weight of a cubic inch. | | Number of cubic inches in a lb. | Weight of a cubic yard in tons. |
|---|---|---|---|---|---|---|
| | In oz. | In lbs. | In oz. | In lbs. | | |
| | 1. | 2. | 3. | 4. | 5. | 6. |
| Platina | 19500 | 1218.75 | 11 284 | .7053 | 1.417 | — |
| Copper, cast | 8788 | 549.25 | 5.086 | .3178 | 3.146 | — |
| Copper, sheet | 8915 | 557.18 | 5.159 | .3225 | 3.103 | — |
| Brass, cast | 8396 | 524.75 | 4.852 | .3037 | 3 293 | — |
| Iron, cast | 7271 | 454 43 | 4.203 | .263 | 3.802 | — |
| Iron, bar | 7631 | 476 93 | 4.410 | .276 | 3.623 | — |
| Lead | 11344 | 709.00 | 6.456 | .4103 | 2.437 | — |
| Steel, soft | 7833 | 489.56 | 4 527 | .2833 | 3.530 | — |
| Steel, hard | 7816 | 488.50 | 4.517 | .2827 | 3.537 | — |
| Zinc, cast | 7190 | 449.37 | 4.156 | .26 | 3.845 | — |
| Tin, cast | 7292 | 455.75 | 4.215 | .2636 | 3.790 | — |
| Bismuth | 9880 | 619.50 | 5.710 | .3585 | 2.789 | — |
| Gun Metal | 8784 | 549.00 | 5.0775 | .3177 | 3.147 | — |
| Sand | 1520 | 95.00 | .8787 | .055 | 18.190 | 1.145 |
| Coal | 1250 | 78.12 | .7225 | .0452 | 22.120 | 0.941 |
| Brick | 2 00 | 125.00 | 1.156 | .0723 | 13.824 | 1.506 |
| Stone, paving | 2416 | 151.00 | 1.396 | .0873 | 11.443 | 1.820 |
| Stone, Bristol | 2554 | 159.62 | 1.478 | .0923 | 10.825 | 1.924 |
| Grindstone | 2143 | 133.94 | 1.240 | .07751 | 12.901 | 1.614 |
| Chalk, British | 2781 | 173.81 | 1.609 | .1005 | 9.941 | 2 095 |
| Jet | 1259 | 78.69 | 0.729 | .04553 | 21.959 | 0.948 |
| Salt | 2130 | 133.12 | 1.233 | .07704 | 12.980 | 1.604 |
| Slate | 2672 | 167.00 | 1.544 | .0967 | 10.347 | 2.012 |
| Marble | 2742 | 171.37 | 1.585 | .0991 | 10 083 | 2.065 |
| White Lead | 3160 | 197.50 | 1.826 | .1143 | 8.750 | — |
| Glass | 2880 | 180.00 | 1.664 | .1042 | 9.600 | — |
| Tallow | 945 | 59.06 | .5462 | .0342 | 29.258 | — |
| Cork | 240 | 15.00 | .138 | .0087 | 115.200 | — |
| Larch | 544 | 34.00 | .315 | .0197 | 50.823 | — |
| Elm | 556 | 34.75 | .321 | .0201 | 49.726 | — |
| Pine, pitch | 660 | 41.25 | .382 | .024 | 41.890 | — |
| Beech | 696 | 43.50 | .403 | .0252 | 39.724 | — |
| Teak | 745 | 46.56 | .431 | .027 | 37.113 | — |
| Ash | 760 | 47.50 | .440 | .0275 | 36.370 | — |
| Mahogany | 852 | 53.25 | .493 | .0308 | 32.449 | |
| Oak | 970 | 60.62 | .561 | .0351 | 23.505 | — |
| Oil of Turpentine | 870 | 54.37 | .503 | .0315 | 31.771 | — |
| Olive Oil | 915 | 57.18 | .529 | .0331 | 30.220 | — |
| Linseed Oil | 932 | 58.25 | .539 | .0337 | 29.665 | — |
| Spirits, proof | 927 | 57.93 | .536 | .03352 | 29.288 | — |
| Water, distilled | 1000 | 62.50 | .578 | .03617 | 27.648 | 0.753 |
| Water, sea | 1028 | 64.25 | .594 | .0372 | 26.894 | 0.774 |
| Tar | 1015 | 63.43 | .587 | .0367 | 27.242 | — |
| Vinegar | 1026 | 64.12 | .593 | .037 | 26.949 | — |
| Mercury (at 60°) | 13568 | 848.00 | 7.851 | .4908 | 2.037 | — |

## THE WEIGHT OF ONE LINEAL FOOT OF WROUGHT IRON—FLAT.

| SIZE. Ins. | In. | WEIGHT. lbs. | SIZE. Ins. | In. | WEIGHT. lbs. | SIZE. Ins. | In. | WEIGHT. lbs. |
|---|---|---|---|---|---|---|---|---|
| 1 | by ¼ | .... 0.85 | 1¾ | by ½ | .... 2.96 | 2¼ | by ¾ | ... 5.70 |
| 1¼ | by ¼ | .... 1.06 | 2 | by ½ | .... 3.38 | 2½ | by ¾ | ... 6.33 |
| 1½ | by ½ | .... 1.27 | 2¼ | by ½ | .... 3.80 | 2¾ | by ¾ | ... 6.97 |
| 1¾ | by ¼ | .... 1.48 | 2½ | by ½ | .... 4.22 | 3 | by ¾ | ... 7.60 |
| 2 | by ¼ | .... 1.69 | 2¾ | by ½ | .... 4.65 | 3¼ | by ¾ | ... 8.24 |
| 2¼ | by ¼ | .... 1.90 | 3 | by ½ | .... 5 07 | 3½ | by ¾ | ... 8.87 |
| 2½ | by ¼ | .... 2.11 | 3¼ | by ½ | .... 5.49 | 3¾ | by ¾ | ... 9.51 |
| 2¾ | by ¼ | ..... 2.32 | 3½ | by ½ | .... 5.92 | 4 | by ¾ | ... 10.14 |
| 3 | by ¼ | .... 2.53 | 3¾ | by ½ | .... 6.33 | 4¼ | by ¾ | ... 10.77 |
| 3¼ | by ¼ | .... 2.75 | 4 | by ½ | .... 6.76 | 4½ | by ¾ | ... 11.41 |
| 3½ | by ¼ | .... 2.96 | 4¼ | by ½ | .... 7.18 | 4¾ | by ¾ | ... 12.04 |
| 3¾ | by ¼ | .... 3.17 | 4½ | by ½ | .... 7.60 | 5 | by ¾ | ... 12.67 |
| 4 | by ¼ | .... 3.38 | 4¾ | by ½ | .... 8.03 | 5¼ | by ¾ | ... 13.31 |
| 4½ | by ¼ | .... 3.59 | 5 | by ½ | .... 8 45 | 5½ | by ¾ | ... 13.94 |
| 4½ | by ¼ | .... 3.80 | 5¼ | by ½ | .... 8.87 | 5¾ | by ¾ | ... 14.57 |
| 4¾ | by ¼ | .... 4.01 | 5½ | by ½ | .... 9.30 | 6 | by ¾ | ... 15.21 |
| 5 | by ¼ | .... 4.22 | 5¾ | by ½ | .... 9.72 | | | |
| 5¼ | by ¼ | .... 4.44 | 6 | by ½ | ... 10.14 | | | |
| 5½ | by ¼ | .... 4.65 | | | | 1½ | by 1 | ... 5.07 |
| 5¾ | by ¼ | .... 4.86 | | | | 2 | by 1 | ... 6.76 |
| 6 | by ¼ | .... 5.07 | 1 | by ¾ | .... 2.53 | 3 | by 1 | ... 10.14 |
| | | | 1¼ | by ¼ | .... 3.17 | 4 | by 1 | ... 13.52 |
| 1 | by ½ | .... 1.69 | 1½ | by ¾ | .... 3.80 | 5 | by 1 | ... 16.90 |
| 1¼ | by ½ | .... 2.11 | 1¾ | by ¾ | .... 4.44 | 6 | by 1 | ... 20.28 |
| 1½ | by ½ | .... 2.53 | 2 | by ¾ | .... 5.07 | 7 | by 1 | ... 23.66 |

## WEIGHT OF ROUND IRON PER LINEAL FOOT.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1/4 in. | 3/8 in. | 1/2 in. | 5/8 in. | 3/4 in. | 7/8 in | 1 in. | 1 1/8 in. |
| .165 | .373 | .663 | 1.043 | 1.493 | 2.082 | 2.654 | 3.360 |
| 1 1/4 in. | 1 3/8 in. | 1 1/2 in. | 1 5/8 in. | 1 3/4 in. | 1 7/8 in. | 2 in. | 2 1/8 in. |
| 4.172 | 5.019 | 5.972 | 7.010 | 8.128 | 9.333 | 10.616 | 11.988 |
| 2 1/4 in. | 2 3/8 in. | 2 1/2 in. | 2 5/8 in. | 2 3/4 in. | 2 7/8 in. | 3 in. | 3 1/8 in. |
| 13.440 | 14.975 | 16.688 | 18.293 | 20.076 | 21.944 | 23.888 | 25.926 |
| 3 1/4 in. | 3 3/8 in. | 3 1/2 in. | 3 5/8 in. | 3 3/4 in. | 3 7/8 in. | 4 in. | 4 1/4 in. |
| 28.040 | 30.240 | 32.512 | 34.886 | 37.332 | 39.864 | 42.464 | 47.952 |
| 4 1/2 in. | 4 5/8 in. | 4 3/4 in. | 4 7/8 in. | 5 in. | 5 1/4 in. | 5 1/2 in. | 6 in. |
| 53.760 | 56.788 | 59.900 | 63.094 | 66.752 | 73.172 | 80.304 | 95 552 |

## WEIGHT OF SQUARE IRON PER LINEAL FOOT.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1/4 in. | 3/8 in. | 1/2 in | 5/8 in | 3/4 in. | 7/8 in. | 1 in. | 1 1/8 in. |
| .211 | .475 | .845 | 1.320 | 1.901 | 2.588 | 3.380 | 4.278 |
| 1 1/4 in. | 1 3/8 in. | 1 1/2 in. | 1 5/8 in. | 1 3/4 in. | 1 7/8 in. | 2 in. | 2 1/8 in. |
| 5.280 | 6.390 | 7.604 | 8.926 | 10.352 | 11.883 | 13.520 | 15.263 |
| 2 1/4 in. | 2 3/8 in. | 2 1/2 in. | 2 5/8 in. | 2 3/4 in. | 2 7/8 in. | 3 in. | 3 1/8 in. |
| 17.112 | 19.066 | 21.120 | 23.292 | 25.560 | 27.939 | 30.416 | 33.010 |
| 3 1/4 in. | 3 3/8 in. | 3 1/2 in. | 3 5/8 in. | 3 3/4 in. | 3 7/8 in. | 4 in. | 4 1/8 in. |
| 35.704 | 38.503 | 41.408 | 44.418 | 47.534 | 50.756 | 54.084 | 57.517 |
| 4 1/4 in. | 4 3/8 in. | 4 1/2 in. | 4 5/8 in. | 4 3/4 in. | 4 7/8 in. | 5 in. | 5 1/8 in. |
| 61.055 | 64.700 | 68.448 | 72.305 | 76.264 | 80.333 | 84.480 | 88.784 |

## NUMBER OF NAILS PER POUND.

| Size of Nail. | No. per pound. | Length. | Size of Nail. | No. per pound. | Length. |
|---|---|---|---|---|---|
| 3d fine, | 800 | 1⅛ inches. | 6d slating, | 124 | 2 inches. |
| 3d | 4 0 | 1¼ " | 6d flooring, | 184 | 2 " |
| 4d light, | 400 | 1⅜ " | 8d " | 100 | 2½ " |
| 4d | 288 | 1 7-16 " | 10d " | 80 | 3 " |
| 5d | 200 | 1¾ " | 12d " | 65 | 3¼ " |
| 6d | 152 | 2 " | 3d box, | 560 | 1¼ " |
| 7d | 120 | 2¼ " | 4d " | 440 | 1½ " |
| 8d | 92 | 1½ " | 5d " | 272 | 1¾ " |
| 9d | 80 | 2¾ " | 6d " | 250 | 2 " |
| 10d | 68 | 3 " | 7d " | 176 | 2¼ " |
| 12d | 48 | 3¼ " | 8d " | 140 | 2½ " |
| 20d | 34 | 4 " | 9d " | 120 | 2¾ " |
| 30d | 24 | 4½ " | 10d " | 100 | 3 " |
| 40d | 8 | 5 " | 4d fine fin'g | 544 | 1½ " |
| 50d | 14 | 5½ " | 5d " | 480 | 1¾ " |
| 60d | 10 | 6 " | 6d " | 272 | 2 " |
| 3d slating, | 300 | 1¼ " | 8d " | 165 | 2½ " |
| 4d " | 200 | 1½ " | 10d " | 110 | 3 " |
| 5d " | 150 | 1¾ " | | | |

## IRON REQUIRED FOR ONE MILE OF TRACK.

TONS OF IRON.

RULE.—To find the number of tons of rail to the mile, divide the weight per yard by 7, and multiply by 11, thus: for 56 pound rail, divide 56 by 7, equal 8, multiplied by 11 equal 88 tons, for one mile of single track.

| Weight of Rail per Yard. | Tons per mile. | Weight of Rail per Yard. | Tons per mile. |
|---|---|---|---|
| 12 lbs. | 18 tons 1920 lbs. | 45 lbs. | 70 tons 1600 lbs. |
| 14 " | 22 " ..... " | 48 " | 75 " 960 " |
| 16 " | 25 " 320 " | 50 " | 78 " 1280 " |
| 18 " | 28 " 640 " | 52 " | 81 " 1600 " |
| 20 " | 31 " 960 " | 56 " | 88 " ..... " |
| 22 " | 34 " 1280 " | 57 " | 89 " 1280 " |
| 25 " | 39 " 640 " | 60 " | 94 " 640 " |
| 26 " | 40 " 1920 " | 62 " | 97 " 960 " |
| 27 " | 42 " 960 " | 64 " | 100 " 1280 " |
| 28 " | 44 " ..... " | 65 " | 102 " 320 " |
| 30 " | 47 " 320 " | 68 " | 106 " 1920 " |
| 33 " | 51 " 1920 " | 70 " | 110 " ..... " |
| 35 " | 55 " ..... " | 72 " | 113 " 320 " |
| 40 " | 62 " 1920 " | 76 " | 119 " 960 " |

## SPLICES AND BOLTS FOR ONE MILE OF TRACK.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30 | feet of | Rail | requires | 740 | Splices ; | 1408 | Bolts | and Nuts. |
| 28 | " | " | " | 754 | " | 1508 | " | " |
| 27 | " | " | " | 782 | " | 1564 | " | " |
| 25 | " | " | " | 844 | " | 1688 | " | " |
| 24 | " | " | " | 880 | " | 1760 | " | " |

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## WEIGHT OF ONE HUNDRED BOLTS OF THE ENUMERATED SIZES.

### WITH SQUARE HEADS AND NUTS.

| Lengths. | ¼ in. | 5-16 in. | ⅜ in. | 7-16 in. | ½ in. | ⅝ in. | ¾ in. | ⅞ in. |
|---|---|---|---|---|---|---|---|---|
| 1½ in. | 4.16 | 7.59 | 10.62 | 15.94 | 23.87 | 39.31 | ..... | ..... |
| 1¾ " | 4.22 | 7.87 | 11.72 | 16.90 | 25.06 | 41.48 | ..... | ..... |
| 2 " | 4.75 | 8.56 | 12.38 | 18.25 | 26.44 | 45 69 | 73.62 | ..... |
| 2¼ " | 5.34 | 9.12 | 12.90 | 19.38 | 28.62 | 49.50 | 76. | ..... |
| 2½ " | 5.97 | 9.59 | 11.69 | 20 69 | 29.50 | 51.25 | 79.75 | ..... |
| 2¾ " | 6.50 | 10.44 | 16.47 | 21.50 | 31.16 | 53. | 83. | ..... |
| 3 " | ..... | 11.78 | 17.88 | 22.38 | 32.44 | 56. | 85.38 | 127.25 |
| 3½ " | ..... | 11.81 | 18.94 | 26.19 | 39.75 | 63.12 | 93.44 | 140.56 |
| 4 " | ..... | ..... | 20.59 | 28 87 | 42.50 | 74.87 | 108.12 | 148.37 |
| 4½ " | ..... | ..... | 21 69 | 29.87 | 44.87 | 79.62 | 113.12 | 158.76 |
| 5 " | ..... | ..... | 23.62 | 32.31 | 48.81 | 83. | 122. | 167.25 |
| 5½ " | ..... | ..... | 25.81 | 34.44 | 51.38 | 87 88 | 128.62 | 174.88 |
| 6 " | ..... | ..... | 26.87 | 36.62 | 53.31 | 92.38 | 131.75 | 204.25 |
| 6½ " | ..... | ..... | ..... | ..... | 56.87 | 96 88 | 139.56 | 214.69 |
| 7 " | ..... | ..... | ..... | ..... | 59.12 | 99.87 | 145.50 | 228.44 |
| 7½ " | ..... | ..... | ..... | ..... | 61.87 | 105.75 | 150.88 | 235.31 |
| 8 " | ..... | ..... | ..... | ..... | 64.44 | 109.50 | 157.12 | 239.88 |
| 9 " | ..... | ..... | ..... | ..... | 70.50 | 118.12 | 169.62 | 258 12 |
| 10 " | ..... | ..... | ..... | ..... | 77. | 128.13 | 184. | 276.18 |
| 11 " | ..... | ..... | ..... | ..... | 82.88 | 136.19 | 195.13 | 295.69 |
| 12 " | ..... | ..... | ..... | ..... | 86.37 | 144.87 | 209.75 | 311.94 |
| 13 " | ..... | ..... | ..... | ..... | 92. | 155.50 | 219.37 | 335.81 |
| 14 " | ..... | ..... | ..... | ..... | 97.75 | 163.58 | 237.50 | 351.88 |
| 15 " | ..... | ..... | ..... | ..... | 103.25 | 170.75 | 249 06 | 391.75 |

## WEIGHT OF SHEET AND PLATE IRON.

THICKNESS BY BIRMINGHAM WIRE GAUGE AND INCHES. WEIGHT OF A SQUARE FOOT IN POUNDS.

| THICKNESS. | | Weight, | THICKNESS. | | Weight, |
|---|---|---|---|---|---|
| B. W. Gauge. | Part of an inch. | Pounds. | B. W. Gauge. | Part of an inch. | Pounds. |
| | 1-16 or ·0625 | 2·518 | 3 | ·259 | 10·37 |
| 14 | ·083 | 3·35 | | 9-32 or ·2812 | 11 38 |
| | 3-32 or ·0937 | 3 78 | 1 | ·3 | 12·15 |
| 12 | ·100 | 4·4 | | 5-16 or ·3125 | 12·58 |
| | ⅛ or ·125 | 5 054 | 0 | ·340 | 13·750 |
| 9 | ·148 | 5·98 | | 11-32 or ·3437 | 13·875 |
| | 5-32 or 1562 | 6·305 | 00 | ·380 | 15·26 |
| 7 | ·180 | 7·27 | | 13-32 or ·4062 | 16 34 |
| | 3-16 or ·1875 | 7·578 | 000 | ·425 | 17·125 |
| 6 | ·203 | 8·005 | | 8-16 or ·4375 | 17 65 |
| | 7-32 or ·2187 | 8·79 | 0000 | ·454 | 18 30 |
| 5 | ·22 | 8·912 | | 15-32 or ·4607 | 18·90 |
| | ¼ or ·25 | 10·09 | 00000 | ½ or ·50 | 20 00 |

For STEEL PLATES multiply tabular number above (for size) by 1·01

## WEIGHT OF SHEET AND PLATE IRON.

THICKNESS IN INCHES. WEIGHT OF A SQUARE FOOT IN POUNDS.

| Inches Thick. | lbs. per Sq. Foot. | Inches Thick. | lbs. per Sq. Foot. | Inches Thick. | lbs. per Sq. Foot. |
|---|---|---|---|---|---|
| 9-16 | 22·5 | 1 ¾ | 70·62 | 3 ⅞ | 156·51 |
| ⅝ | 25·21 | 13-16 | 73·14 | 4 | 161 55 |
| 11-16 | 27·75 | ⅞ | 75·58 | ⅛ | 166·6 |
| ¾ | 30·25 | 15-16 | 78·20 | ¼ | 171·76 |
| 13-16 | 32·75 | 2 | 80·75 | ⅜ | 176·71 |
| ⅞ | 35 26 | ⅛ | 85·75 | ½ | 181·77 |
| 15-16 | 37·75 | ¼ | 90 81 | ⅝ | 186·79 |
| 1 | 40·35 | ⅜ | 95 86 | ¾ | 191·84 |
| 1-16 | 42 87 | ½ | 100·9 | ⅞ | 196·9 |
| ⅛ | 45·4 | ⅝ | 105 95 | 5 | 201·85 |
| 3-16 | 47 9 | ¾ | 111· | ⅛ | 206 9 |
| ¼ | 50·45 | ⅞ | 116·1 | ¼ | 211·95 |
| 5-16 | 52 96 | 3 | 121·15 | ⅜ | 217· |
| ⅜ | 55·45 | ⅛ | 126·21 | ½ | 222 05 |
| 7-16 | 58·01 | ¼ | 131·26 | ⅝ | 227·01 |
| ½ | 60·52 | ⅜ | 136·32 | ¾ | 232·15 |
| 9-16 | 63·05 | ½ | 141·37 | ⅞ | 237·2 |
| ⅝ | 65·56 | ⅝ | 146·41 | 6 | 242·25 |
| 11-16 | 68·11 | ¾ | 151·46 | | |

For STEEL PLATES multiply tabular number above (for size) by 1·01.

## SHRINKAGE OF CASTINGS.

| | | |
|---|---|---|
| Cast iron | $\frac{1}{8}$ | in. per lineal ft. |
| Brass | $\frac{3}{16}$ | " " |
| Lead | $\frac{1}{8}$ | " " |
| Tin | $\frac{1}{12}$ | " " |
| Zinc | $\frac{5}{16}$ | " " |

## SIZES AND WEIGHTS OF WROUGHT IRON WELDED TUBES FOR GAS, STEAM AND WATER.

| Inside Diameter. | Weight per Foot. | Inside Diameter. | Weight per Foot. |
|---|---|---|---|
| $\frac{1}{2}$ inch. | .24 | $2\frac{1}{2}$ inches. | 5.77 |
| $\frac{1}{4}$ " | .42 | 3 " | 7 54 |
| $\frac{3}{8}$ " | .56 | $3\frac{1}{2}$ " | 9.05 |
| $\frac{1}{2}$ " | .85 | 4 " | 10.72 |
| $\frac{3}{4}$ " | 1.12 | $4\frac{1}{2}$ " | 12.49 |
| 1 " | 1.67 | 5 " | 14.56 |
| $1\frac{1}{4}$ " | 2.25 | 6 " | 18.77 |
| $1\frac{1}{2}$ " | 2.69 | 7 " | 23.41 |
| 2 " | 3.66 | 8 " | 28.35 |

## FORCE OF GRAVITY.

A body falling gains, in the first second of time, a velocity of 32 feet per second and falls a distance of 16 feet, 16 being the mean between 0, the velocity at the beginning, and 32 the velocity gained at the end of the first second

The second second the body commences with a velocity of 32 feet, and under the constant force of gravity gains 32 feet more velocity, making 64 feet $=4 \times 16$. It commences the third second with a velocity of 64 feet and gains 32 feet more, making 96 feet $= 6 \times 16$ feet. The mean between 32 feet, the velocity at the beginning of the second second, and 64 feet, the velocity at the close, is 48 feet $= 3 \times 16$ feet. The mean between 64 feet, the velocity at the beginning of the third second, and 96 feet, the velocity at the close, is 80 feet $= 5 \times 16$. Hence, the velocities are as the even numbers, and the distances as the odd numbers.

In any number of seconds, a body falls 16 feet $\times$ number of seconds, or,

Let $v$ be velocity of falling body.

" $d$ " distance fallen through perpendicular in feet.

" $t$ " time in seconds. Then

$$v = 32\ t,$$
$$d = 16\ t^2$$
$$v^2 = 64\ d,$$

or, putting these formula into words.

1. To find the depth of a shaft by letting a body fall down, when the time is known. Square the number of seconds it takes to fall; multiply them by 16 and the result is the depth in feet.

2. To learn how long it will take a body to fall down a shaft, when the depth is known, multiply the depth by 64, and take out the square root. The root is the velocity in seconds when it reaches the bottom, one-half of which is the mean velocity in feet per seconds, which, divided into the distance in feet, gives the time taken in falling.

*Example:*

The East Mine shaft is 1600 feet deep. How long will it take a stone to fall down it, and what speed will it have attained when it strikes the bottom ?

*Solution:*

Depth of shaft, 1600 feet.

$$1600 \times 64 = 102{,}400$$

$\sqrt{102{,}400} = 320.$ $\quad \frac{320}{2} = 160$ mean velocity in feet per second, and $\frac{1600}{160} = 10$ seconds to fall to bottom, and the speed per second when it strikes bottom will be 320 feet.

# CHEMICAL MEMORANDA.

A simple or elementary substance is a body that cannot be resolved or separated into any simpler substances—as oxygen, carbon, iron.

A compound substance is one consisting of two or more constituents—as water, carbonic acid gas, olefiant gas.

The equivalent number or atomic weight expresses the relations that subsist between the different proportions by weight in which substances unite chemically with each other.

The eqivalent of a compound is the sum of the equivalents of its constituents.

Specific gravity expresses the difference that subsists between the weights of equal volumes of bodies.

So far as chemists have been able to discover, there are about 65 elementary or simple substances.

No compound body contains all the elementary substances. Most compounds are composed of two, three or four elements.

## TABLE OF ELEMENTARY SUBSTANCES.

| Names of Elements. | Symbol. | Atomic Weight. |
|---|---|---|
| Aluminum | Al | 27.4 |
| Antimony | Sb | 122 |
| Arsenic | As | 75 |
| Barium | Ba | 137 |
| Beryllium | Be | 9.4 |
| Bismuth | Bi | 210 |
| Boron | B | 11 |
| Bromine | Br | 80 |
| Cadmium | Cd | 112 |
| Calcium | Ca | 40 |
| Carbon | C | 12 |
| Cerium | Ce | 92 |
| Chlorine | Cl | 35.5 |
| Chromium | Cr | 52.2 |
| Cobalt | Co | 58.8 |
| Copper | Cu | 63.4 |
| Fluorine | F | 19 |
| Gold | Au | 197 |

| Names of Elements. | Symbol. | Atomic Weight. |
|---|---|---|
| Hydrogen | H | 1 |
| Indium | In | 74 |
| Iodine | I | 127 |
| Iridium | Ir | 198 |
| Iron | Fe | 56 |
| Lanthanum | Ln | 93 |
| Lead | Pb | 207 |
| Lithium | Li | 7 |
| Magnesium | Mg | 24 |
| Manganese | Mn | 55 |
| Mercury | Hg | 200 |
| Molybdenum | Mo | 96 |
| Nickel | Ni | 58.8 |
| Niobium | Nb | 95 |
| Nitrogen | N | 14 |
| Osmium | Os | 199 |
| Oxygen | O | 16 |
| Pallidium | Pd | 106.6 |
| Phosphorus | P | 31 |
| Platinum | Pt | 197.4 |
| Potassium | K | 39.1 |
| Rhodium | R | 104 |
| Rubidium | Rb | 85 |
| Ruthenium | Ru | 104 |
| Selenium | Se | 79 |
| Silicium or Silicon | Si | 28 |
| Silver | Ag | 108 |
| Sodium | Na | 23 |
| Strontium | Sr | 87.6 |
| Sulphur | S | 32 |
| Tantalum | Ta | 182 |
| Tellurium | Te | 128 |
| Thallium | Tl | 204 |
| Thorium | Th | 231.5 |
| Tin | Sn | 118 |
| Titanium | Ti | 50 |
| Tungsten | W | 184 |
| Uranium | U | 120 |
| Vanadium | V | 51 2 |
| Yttrium | Y | 61.7 |
| Zinc | Zn | 65 |
| Zirconium | Zr | 89.6 |

## LIST OF SOME BINARY COMPOUNDS.

| Name of Compound. | Symbol. |
|---|---|
| Ammonia | $N H_3$ |
| Bisulphide of Carbon | $C S_2$ |
| Carbonic acid gas | $C O_2$ |
| Carbonic oxide | $C O$ |
| Cyanogen | $N C_2$ |
| Hydrochloric acid | $H Cl$ |
| Light carbureted hydrogen | $C H_4$ |
| Nitric acid | $N O_5$ |
| Olefiant gas | $C_2 H_4$ |
| Peroxide of iron | $Fe_2 O_3$ |
| Protoxide of iron | $Fe O$ |
| Sulphurous acid gas | $S O_2$ |
| Sulphuric acid | $H_2 SO_4$ |
| Sulphureted hydrogen | $H_2 S$ |
| Water | $H_2 O$ |

## NOMENCLATURE.

The compounds of the non-metallic elements with the metals and with each other have names ending in "ide" or "uret;" as Fe S, sulphide or sulphuret of iron.

When two or more equivalents of the non-metallic elements enter into combination, the number of equivalents is expressed by prefixes.

Bi means 2 eq., as $N O_2$ binoxide of nitrogen

Ter " 3 eq., as $Sb_2 S_3$ tersulphide of antimony.

Penta " 5 eq.,

Sesqui " 1½ eq., (= 2 to 3), as $Fe_2 O_3$ sesquioxide of iron.

Proto " first, or 1 to 1, as Fe O protoxide of iron.

Sub " under, as $Cu_2 O$ suboxide of copper.

Per " the highest, as $Cl O_4$ protoxide of chlorine.

Alkalies neutralize acids, forming salts.

The terminations "ic" and "ous" are used for acids, the former representing a higher state of oxidation than the latter.

When a substance forms more than two acid compounds, the prefixes "hypo," *under*, and "hyper," *above*, are used.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases, they are said to be hydrated.

## COMMON NAMES OF CERTAIN CHEMICAL SUBSTANCES.

| | |
|---|---|
| Aqua fortis | Nitric acid. |
| Bluestone, or blue vitriol | Sulphate of copper. |
| Calomel | Chloride of mercury. |
| Chloroform | Chloride of formyle. |
| Common salt | Chloride of sodium. |
| Copperas, or green vitriol | Sulphate of iron. |
| Corrosive sublimate | Bichloride of mercury. |
| Dry Alum | Sulphate of alumina and potash. |
| Epsom salts | Sulphate of magnesia. |
| Ethiops mineral | Black sulphide of mercury. |
| Galena | Sulphide of lead. |
| Glauber's salts | Sulphate of soda. |
| Iron pyrites | Bisulphide of iron. |
| Jeweler's putty | Oxide of tin. |
| King's yellow | Sulphide of arsenic. |
| Laughing gas | Protoxide of nitrogen. |
| Lime | Oxide of calcium. |
| Lunar caustic | Nitrate of silver. |
| Mosaic gold | Bisulphide of tin. |
| Nitre, or salt petre | Nitrate of potash. |
| Oil of vitriol | Sulphuric acid. |
| Realga | Sulphide of arsenic. |
| Red lead | Oxide of lead. |
| Rust of iron | Oxide of iron. |
| Soda | Oxide of sodium. |
| Spirit of Hartshorn | Ammonia. |
| Spirit of salt | Hydrochloric acid. |
| Stucco, or plaster of Paris | Sulphate of lime. |
| Sugar of lead | Acetate of lead. |
| Vermillion | Sulphide of mercury. |
| Vinegar | Acetic acid. |
| Volatile alkal | Ammonia. |
| Water | Oxide of hydrogen. |
| White Vitriol | Sulphate of zinc. |

# TABLE

SHOWING THE NUMBER OF VOLUMES OF VARIOUS GASES WHICH 100 VOLUMES OF WATER, AT 60° FAHR. AND 30 INCHES BAROMETRIC PRESSURE, CAN ABSORB.

(*Dr. Frankland.*)

| | | |
|---|---|---|
| Ammonia | 7806 | volumes. |
| Sulphurous acid | 3300 | " |
| Sulphureted hydrogen | 253 | " |
| Carbonic acid | 100 | " |
| Olefiant gas | 12.5 | " |
| Illuminating hydrocarbons | Not determined, but probably more soluble than olefiant gas. | |
| Oxygen | 3.7 | volumes. |
| Carbonic oxide | 1.56 | " |
| Nitrogen | 1.56 | " |
| Hydrogen | 1.56 | " |
| Light carbureted hydrogen | 1.60 | " |

When water has been saturated with one gas and is exposed to the influence of a second, it usually allows a portion of the first to escape, whilst it absorbs an equivalent quantity of the second. In this way a small portion of a not easily soluble gas can expel a large volume of an easily soluble one.

# USEFUL MEMORANDA.

| | |
|---|---|
| Mean circumference of the earth | 24,856 miles. |
| Diameter of the earth | 7,921 " |
| Radius of the equator | 20,921,180 feet. |
| Polar semi-axis | 20,853,180 " |
| Length of geographical or nautical mile | 6075.66 " |
| Ratio of nautical to English mile | 1.15068 to 1. |
| Length of pendulum at the equator | 39.01326 inches. |
| Length of pendulum at New York | 39.10153 " |
| Force of gravity at New York, feet per second | 32.1594 |
| Tropical year | 365.242245 days. |
| Length of an arc | = No. of Deg. $\times$ rad. $\times$ .01745. |
| Circumference of a circle, | Diam. $\times$ 3.1416. |
| Area of do | Diam.$^2$ $\times$ .7854. |
| Diameter of do | Cir. $\times$ .31831. |
| Side of an equal square | Diam. $\times$ .8862. |
| Diameter of equal circle | $\sqrt{}$ Area $\times$ 1.12837. |
| Ellipse, area | T. axis $\times$ C. axis $\times$ .7854. |
| Sphere, surface | Diam.$^2$ $\times$ 3.1416, |
| " solidity | Diam.$^3$ $\times$ .5236. |
| Square feet | Circular inches $\times$ .00456. |
| " " | Square inches $\times$ .00695. |
| " yards | Square feet $\times$ .111. |
| Cubic feet | Cubic inches $\times$ .00058. |
| " yards | Cubic feet $\times$ .03704. |
| " " | Cylindrical feet $\times$ .02909. |
| English miles | Lineal feet $\times$ .00019, or lineal yards $\times$ .000568. |
| " acres | Square yards $\times$ .00026067. |
| Parabola, area | $\frac{2}{3}$ of base $\times$ height. |
| 1 square foot | 183.346 circular inches. |
| Cub. ins. in imperial gal | 277.274 |
| " " in stand'd U. S. gal | 231 |
| " " in beer gallon | 282 |
| " foot | 6.232 imperial gallons. |
| " inches $\times$ .028848 | pints. |
| " " $\times$ .014424 | quarts. |
| " " $\times$ 003606 | gallons. |
| " " $\times$ .0004508 | bushels. |
| " " $\times$ .00005635 | quarters. |
| " " $\times$ 0005787 | cubic feet. |
| " " $\times$ .0000214 | " yards. |

| | | |
|---|---|---|
| Cub. inches | × .0163 | = French litres. |
| " " | × .257 | lb cast iron. |
| " " | × .278 | " wrought iron. |
| " " | × .491 | " quicksilver. |
| " " | × .4112 | " lead. |
| " " | × .2632 | " tin. |
| " " | × .2597 | " zinc. |
| " " | × .3201 | " copper |
| " " | × .3058 | " brass. |
| Statute acres | × 4840 | square yards. |
| Square links | × .4356 | " feet. |
| " feet | × 2.3 | " links. |
| Links | × .22 | yards. |
| " | × 66 | feet. |
| Feet | × 1.5 | links. |
| Cubic feet | × 2.200 | cylindrical inches. |
| Cylind. ins | × .0004546 | cubic yards. |
| Imperial gallons | × .1604 | " feet. |
| Standard gallons | × .1331 | " feet. |
| Cubic feet | × .779 | bushels. |
| Bushels | × .0476 | cubic yards. |
| " | × 1 284 | " feet. |
| " | × 2218.2 | " inches. |
| Statute miles | × .869 | mean geographical miles. |
| Pounds avoir. | × 7000 | grains. |
| Grains | × .0001429 | pounds avoirdupois. |
| Pounds avoir. | × .009 | cwts. |
| " " | × 00045 | tons. |
| Tons | × 2,240 | pounds avoirdupois. |
| " | × .984 | tonnes, French. |
| Pounds on the sq. in. | × 144 | pounds on the square foot. |
| Pounds on the sq. ft. | × .007 | pounds on the square inch. |
| Miles per hour | × 1 467 | feet per second. |
| Feet per second | × .682 | miles per hour. |
| French metres | × 3.281 | English feet. |
| " litres | × .2201 | imperial gallons. |
| " hectolitre | × 2.7512 | English bushels. |
| " grammes | × .002205 | pounds avoirdupois. |
| " kilogrammes | × 2.205 | " " |
| Dia. of sphere | × .806 | dimensions of equal cube. |
| " " | × .6667 | length of equal cylinder. |
| One atmosphere | | 14.7 pounds on the sq. inch. |
| " | | 2116 " " foot. |
| " | | 29.922 inches of mercury. |
| " | | 33.9 feet of water. |

## MEASURES OF LENGTH.

The U. S. standard yard is the same as the imperial yard of Great Britain. It is determined as follows: The rod of a pendulum vibrating seconds of mean time in the latitude of London in a vacuum at the level of the sea is divided into 391,393 equal parts, and 360,000 of these parts are 36 inches or 1 standard yard.

An inch is one 500,500,000th part of the earth's polar axis.

Artificers sometimes divide the inch into lines or twelfths, but more commonly into binary divisions—half, quarter, eighth, sixteenths, and thirty-second.

Mechanical engineers divide the inch decimally—10ths. 100ths, 1000th, &c.

Civil engineers divide the foot decimally.

The hand is used for heights of horses and the girths of spars.

The fathom = 2 yards.

The league = 3 nautical miles.

The pace = 3 ft.

The geographical or nautical mile = 1 15th statute mile.

The geographical degree = 60 geographical or nautical miles.

The length of a degree of latitude varies, being 68.72 miles at the equator, 69.05 miles in middle latitudes, and 69.34 miles in the polar regions. A degree of longitude is greatest at the equator, where it is 69.16 miles, and it gradually decreases toward the poles, where it is 0.

---

## TABLE OF MEASURES OF LENGTH.

| Inches. | Hands. | Feet. | Yards. | Fathoms. | Chains. | Fur. | Mile. |
|---|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — | — |
| 4 | 1 | — | — | — | — | — | — |
| 12 | 3 | 1 | — | — | — | — | — |
| 36 | 9 | 3 | 1 | — | — | — | — |
| 72 | 18 | 6 | 2 | 1 | — | — | — |
| 792 | 198 | 66 | 22 | 11 | 1 | — | — |
| 7,920 | 1,980 | 660 | 220 | 110 | 10 | 1 | — |
| 63,360 | 15,840 | 5,280 | 9,760 | 880 | 80 | 8 | 1 |

## MEASURES OF AREA.

(*Used in Engineering and Science.*)

| Sq. inch. | Sq. foot. | Sq. yard. | Sq. mile. |
|---|---|---|---|
| 1 | — | — | — |
| 144 | 1 | — | — |
| 1,296 | 9 | 1 | — |
| — | 27,878,400 | 3,097,600 | 1 |

*Land Measure:*

| | Sq. yards. | Sq. feet. |
|---|---|---|
| Rood (40 perches) | 1,210 | 10,890 |
| Perch | $30\frac{1}{4}$ | $272\frac{3}{4}$ |
| Acre (4 roods, or 10 sq. chains) | 4,840 | 43,560 |

*Used in the Arts:*

| | | |
|---|---|---|
| Square (of roofing or flooring) | — | 100 |

---

## MEASURES OF WEIGHT.

The U. S. standard unit of weight is the Troy pound of the Mint which is the same as the imperial standard pound of Great Britain, and is determined as follows: A cubic inch of distilled water in a vacuum, weighed by brass weights also in a vacuum, at a temperature of 62° Fahrenheit's thermometer, is equal to 252.458 grains, of which the standard Troy pound contains 5760.

The U. S. Avoirdupois is determined from the standard Troy pound, and contains 700 Troy grains.

### Avoirdupois Weight, Unit Equivalents.

| Dr. | Oz. | Lbs. | Cwt. | T. |
|---|---|---|---|---|
| 16 = | 1 | ..... | .... | .... |
| 256 = | 16 = | 1 | .... | .... |
| 25,600 = | 1,600 = | 100 = | 1 | .... |
| 512,000 = | 32,000 = | 2000 = | 20 = | 1 |

### Troy Weight, Unit Equivalents.

| Gr. | Pwt. | Oz. | Lb. |
|---|---|---|---|
| 24 = | 1 | .... | .... |
| 480 = | 20 = | 1 | .... |
| 5760 = | 240 = | 12 = | 1 |

### Long Ton Table.

| Lbs. | | Qr. | | Cwt. | | T. |
|---|---|---|---|---|---|---|
| 28 | = | 1 | | ... | | ... |
| 112 | = | 4 | = | 1 | | ... |
| 2240 | = | 80 | = | 20 | = | 1 |

The gross ton is used in the United States in the Anthracite coal and the wholesale iron and plaster trades.

---

## SOLID MEASURES.

| | Cubic ins. | Cubic ft |
|---|---|---|
| Cubic inch (subdivided decimally) | 1 | ... |
| 1 foot × 1 inch × 1 inch | 12 | ... |
| 1 foot × 1 foot × 1 inch | 144 | ... |
| Cubic foot (subdivided decimally or duodecimally) | 1,728 | 1 |
| Cubic yard | 46,656 | 27 |
| Load of hewn timber | ... | 50 |
| Perch of masonry (=16½ sq. yds. face × 1½ ft. thick) | 24¾ cubic ft. | |
| Cord of Wood | 128 cubic ft. | |

A cubic yard of earth is called a load.

In civil engineering the cubic yard is the unit to which estimates are reduced.

A pile 8 feet long, 4 feet wide and 4 feet high, contains 1 cord, and a cord foot is one foot in length of such a pile.

In measuring timber for shipment one-fifth of the solid contents of round timber is deducted for waste in hewing or sawing

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## MEASURES OF CAPACITY.

The U. S. standard unit of liquid measure is the old English wine gallon, of 231 cubic inches, which is equal to 8.33888 pounds avordupois of distilled water at its maximum density; that is, at the temperature of 39.83° Fahrenheit, the barometer at 30 inches.

The U. S. Standard unit of dry measure is the British Winchester bushel, which is 18½ inches in diameter and 8 inches deep, and contains 2150.42 cubic inches, equal to 77.6274 pounds avoirdupois of distilled water, at its maximum density. A gallon dry measure contains 268.8 cubic inches.

The British imperial standard gallon is a measure that will contain 10 pounds avoirdupois weight distilled water, weighed in air at 62° Fahrenheit, the barometer at 30 inches It contains 277.274 cubic inches.

| Gi. | | Pt. | | Qt. | | Gal. | Bbl. | Hhd. |
|---|---|---|---|---|---|---|---|---|
| 4 | = | 1 | | ... | | ... | ... | ... |
| 8 | = | 2 | | 1 | | ... | .... | .... |
| 32 | = | 8 | = | 4 | = | 1 | .. | ... |
| 1008 | = | 252 | = | 126 | = | $31\frac{1}{2}$ | = 1 | ... |
| 2016 | = | 504 | = | 252 | = | 63 | = 2 | = 1 |

The following denominations are also in use:

42 Gallons make 1 tierce.

2 Hhds. make 1 pipe or butt.

2 Pipes or 4 hhds. make 1 tun.

The denominations barrel and hogshead are used in estimating the capacity of cisterns, reservoirs, vats, &c. In Massachusetts, the barrel is 32 gallons.

The tierce, hogshead, pipe, butt and tun are the names of casks, and do not express any fixed measures. They are usually gauged, and have their capacity in gallons marked on them.

---

## DRY MEASURE.

| Pt. | | Qt. | | Pk. | | Bu. |
|---|---|---|---|---|---|---|
| 2 | = | 1 | | .. | | .. |
| 16 | = | 8 | = | 1 | | .. |
| 64 | = | 32 | = | 4 | = | 1 |

---

## MEASURES OF VALUE.

### United States Money.

The currency of the United States is decimal currency, and is sometimes called Federal money.

The unit is the dollar, and all the other denominations are either divisors or multiples of this unit.

### Unit Equivalents.

| Ml. | | Ct. | | D. | | $ | | E. |
|---|---|---|---|---|---|---|---|---|
| 10 | = | 1 | | .. | | .. | | .. |
| 100 | = | 10 | = | 1 | | .. | | .. |
| 1,000 | = | 100 | = | 10 | = | 1 | | .. |
| 10,000 | = | 1,000 | = | 100 | = | 10 | = | 1 |

The character $ is supposed to be a contraction of U. S. (United States), the U being placed upon the S.

The fineness of gold and silver coins means the proportion of the precious metals which they contain, and is generally expressed in thousandths of their total weight. The fineness of gold coins is also expressed in *carats*, or twenty-fourths of their total weight.

By act of Congress, January 18, 1837, all gold and silver coins must consist of 9 parts (.900) pure metal, and 1 part (.100) alloy. The alloy for gold must consist of equal parts of silver and copper, and the alloy for silver of pure copper.

The three-cent piece is 3 parts ($\frac{3}{4}$) silver, and 1 part ($\frac{1}{4}$) copper.

The nickel cent is 88 parts copper and 12 parts nickel.

The fineness of British gold coins is 22 carats, or $0.916\frac{2}{3}$; of British silver coins, 0.925, and of the coins of most other nations, 0.900.

The franc is the value of 4.5 grammes of pure silver, which, being alloyed with 0.5 grammes of copper, the full weight of the coin is 5 grammes. The fineness is 0.900. The Italian Lira is equal to the franc in weight, fineness, and value.

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## COMPARATIVE TABLE OF MONEYS.

| English. | | U. S. | French. | | U. S. |
|---|---|---|---|---|---|
| 1qr..... ..... | = | $ $.00\frac{1}{2}\frac{2}{4}\frac{1}{0}$ | 1 millime ..... | = | $ .000186 |
| 1d ..... | = | $.02\frac{1}{6}\frac{}{0}$ | 1 centime ..... | = | .00187 |
| 1s..... | = | .242 | 1 franc ..... | = | .186 |
| 4s. 1d. $2\frac{4}{1}\frac{2}{2}\frac{}{1}$qr... | = | 1.00 | | | |
| £1..... | = | 4.84 | | | |

---

## MEASURES OF VELOCITY.

*Speed of turning, or angular velocity*, is expressed in turns per second, per minute, or per hour, or in circular measure per second.

To convert turns into circular measure, multiply by 6.2832.

To convert circular measure into turns, multiply by 0,159155.

COMPARISON OF DIFFERENT MEASURES OF ANGULAR VELOCITY.

| Circular measure per second. | Turns per second. | Turns per minute. | Turns per hour. |
|---|---|---|---|
| 1 | 0.159155 | 9.5493 | 572.958 |
| 6.2832 | 1 | 60 | 3600 |
| 0.10472 | 0.016666 | 1 | 60 |
| 0.001745 | 0.000277 | 0.07666 | 1 |

## MEASURES OF HEAVINESS

are expressed in units of weight per unit of volume; as pounds to the cubic foot.

*Specific gravity* is the ratio of the heaviness of a given substance to the heaviness of pure water, at a standard temperature, which in the United States is 62° Fahr. To convert specific gravity, as estimated in the United States into heaviness in lbs. to the cubic foot, multiply by 62.355

## MEASURES OF PRESSURE.

The intensity of pressure is expressed in units of weight on the unit of area, as pounds on the square inch; or by the height of a column of some fluid; or in *atmospheres*, the unit in this case being the average pressure of the atmosphere at the level of the sea. The following table gives a comparison of various units, in which the intensities of pressures are commonly expressed:

| | Pounds on the square foot. | Pounds on the square inch. |
|---|---|---|
| One pound on the square inch.... | 144 | 1 |
| One pound on the square foot... | 1 | $\frac{1}{144}$ |
| One inch of mercury (that is weight of a column of mercury at 32° Fahr., one in. high) | 70.7275 | 0.491163 |
| One foot of water (at 39.1° Fahr) | 62.425 | 0.4335 |
| One inch of water..... | 5.2021 | 0.036125 |
| One atmosphere, of 29.922 inches of mercury, or 760 millimetres | 2116.3 | 14.7 |
| One foot of air at 32° Fahr., and under the pressure of one atmosphere ..... | 0.080728 | 0.0005606 |

### Comparison of Heads of water in Feet with Pressures in Various Units.

| | | |
|---|---|---|
| One ft. of water at 52.53° Fahr. = | 62.4 | lbs. on the sq. ft. |
| " " | 0.4333 | lb. on the sq. in. |
| " " | 0.0295 | atmosphere. |
| " " | 0.8823 | in. of merc. at 32° |
| " " | 773. | ft. of air at 32°, and one atmosphere. |
| One lb. on the sq. ft. | 0.016026 | ft. of water at 52.3° F. |
| " " in. | 2.308 | ft. of water. |
| One atmosphere of 29.922 in. of mercury | 33.9 | |
| One in. of mercury at 32° | 1.1334 | " " |
| One ft. of air at 32°, and one atmosphere | 0.001294 | " |
| One ft. of average sea water | 1.026 | ft. of pure water. |

## MEASURES OF WORK

are expressed in units of weight lifted through a unit of height; as in lbs. lifted one foot, called *foot-pounds*.

## MEASURES OF POWER

are expressed in units of work done in a unit of time; as in foot-pounds per second, per minute, or per hour; or in conventional units called *horse-powers*.

One *horse-power*, United States measure, = 550 foot-pounds per second = 33,000 foot-pounds per minute = 1,980,000 foot-pounds per hour.

## THE STATICAL MOMENT

of a given weight, relatively to a given vertical plane, is the product of the weight into its horizontal distance from that plane, and is expressed in the same sort of units with work.

### Comparison of Measures of Statical Moment.

| Inch-lb. | | | | |
|---|---|---|---|---|
| 12 | 1 ft-lb. | | | |
| 112 | $9\frac{1}{3}$ = | 1 inch-cwt. | | |
| 1,344 | 112 | 12 = | 1 foot-cwt. | |
| 2,240 | $186\frac{2}{3}$ | 20 | $1\frac{2}{3}$ = | 1 inch-ton. |
| 26,880 | 2240 | 240 | 20 | 12 = 1 foot-ton. |

## ABSOLUTE UNITS OF FORCE.

The "absolute unit of force" is a term used to denote the force which, acting on a unit of mass for a unit of time, produces a unit of velocity.

The unit of time employed is always a second.

The unit of velocity is one foot per second.

The unit of mass is the mass of so much matter as weighs one unit of weight near the level of the sea, and in some definite latitude.

The unit of weight chosen is, sometimes a grain, sometimes a pound avoirdupois; and it is equal to 32.187 of the corresponding absolute units of force.

The proportions borne to each other by the absolute units of force in different countries are nearly the same as those of the units of work, and would be exactly the same but for the variation of the force of gravity in the latitude.

---

## LIGHT.

Velocity of light, 192,000 miles per second, nearly.

### Decomposition of Light.

Violet = maximum chemical ray.
Indigo.
Blue.
Green.
Yellow = maximum light ray.
Orange.
Red = maximum heat ray.

---

## COMBINATIONS OF COLOR.

| Primaries. | | Secondary. |
|---|---|---|
| Red and yellow | form | Orange. |
| Red and Blue | " | Purple. |
| Yellow and blue | " | Green. |

| Secondaries. | | Tertiary. |
|---|---|---|
| Orange and purple | form | Rrown. |
| Orange and Green | " | Grey. |
| Purple and Green | " | Broken Green. |

## CONTRASTS OF COLOR.

| Primary colors. | Secondary in contrast to primary. | Tertiary in contrast to secondary. |
|---|---|---|
| Red | Green | Brown. |
| Yellow | Purple | Grey. |
| Blue | Orange | Broken Green. |

---

## SOUND.

| Velocity in | Ft. per second. | Velocity in | Ft. per second. |
|---|---|---|---|
| Air | 1,142 | Copper | 10,378 |
| Water | 4,900 | Wood | 12,000 to 16,000 |
| Iron | 17,500 | | |

Distant sounds may be heard on a still day:

| | | | |
|---|---|---|---|
| Human voice | 150 yds. | Military band | 5,200 yds. |
| Rifle | 5,300 " | Cannon | 35,000 " |

### TO MEASURE DISTANCES BY SOUND.

RULE: Multiply the time the sound takes in seconds by 1142; the product will be the distance in feet.

NOTE.—Sound in common air moves uniformly at the rate of about 1,142 feet in a second. Cold and uneven surfaces retard its motion a little, and heat accelerates it in a small degree.

EXAMPLE 1: I observed the flash of a gun 30 seconds before I heard the report. How far was it distant from me?

*Answer.*—$30 \times 1{,}142 = 34{,}260$ ft.

EXAMPLE 2: I observed a flash of lightning, and after 6 strokes of my pulse I heard the thunder, and my pulse makes 68 strokes in a minute. How far was the thunder distant from me?

*Answer.*—1 mile, 255.3 yards.

## MISCELLANEOUS ARTICLES.

| | |
|---|---|
| Barrel of tar | 26¼ gallons. |
| Cable's length | 240 yards. |
| Cask of black lead | 11½ cwt. |
| English Chaldron of coal | 25½ cwt. |
| " " coke | 12½ to 15 cwt. |
| Chaldron of coal, heaped measure | 36 bushels. |
| Cord of wood | 128 cubic feet. |
| Dozen | 12 articles. |
| Fagot of steel | 120 lbs. |
| Fodder of lead | 19½ cwt. |
| Gross | 12 dozen. |
| Great gross | 12 gross. |
| Bushel of wheat | 60 pounds. |
| " " indian corn | 56 " |
| " " oats | 32 " |
| " " rye | 56 " |
| " " wheat bran | 20 " |
| Firkin of butter | 56 " |
| Quintal of dry salt fish | 100 " |
| Cask of raisins | 100 " |
| Barrel of flour | 196 " |
| Barrel of beef, pork or fish | 200 " |
| Pig of ballast | 56 " |
| Quire of paper | 24 sheets. |
| Ream of paper | 20 quires or 480 sheets. |
| Bundle | 2 reams. |
| Bale | 5 bundles. |
| Roll of parchment | 60 skins. |
| Score | 20 articles. |

Sheet of paper folded into—

| | | |
|---|---|---|
| 2 | leaves is termed | folio size. |
| 4 | " " | 4to. or quarto. |
| 8 | " " | 8vo. or octavo. |
| 12 | " " | 12mo. or duodecimo. |
| 16 | " " | 16mo. |
| 18 | " " | 18mo. |
| 24 | " " | 24mo. |
| 48 | " " | 48mo. |

### The Feeding Properties of Different Vegetables,

In comparison with 10 lbs. of hay.

| | |
|---|---|
| Hay | 10 |
| Clover hay | 8 |
| Vetch hay | 4 |
| Wheat straw | 52 |
| Barley straw | 52 |
| Oat straw | 55 |
| Pea straw | 6 |
| Potatoes | 28 |
| Old potatoes | 40 |
| Turnips | 60 |
| Carrots | 35 |
| Cabbage | 30 to 40 |
| Peas and beans | 2 to 3 |
| Wheat | 5 |
| Barley | 6 |
| Oats | 5 |
| Rye | 5 |
| Indian corn | 6 |
| Bran | 5 |
| Oil-cake | 2 |

Thus, 2 lbs. of oil-cake is worth as much as 55 lbs. of oat straw.

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## USEFUL INFORMATION.

In Kentucky, 80 pounds of bituminous or cannel coal make a bushel.

In Illinois, 80 pounds of bituminous coal make a bushel.

In Missouri, 80 pounds of bituminous coal make a bushel.

In Indiana, 70 pounds of bituminous coal make a bushel.

In Pennsylvania, 76 pounds of bituminous coal make a bushel.

Coal, corn in the ear, fruit and roots are sold by heaped measure, that is, the bushel is heaped in the form of a cone, which cone must be 19½ inches in diameter (equal to the outside diameter of the standard bushel measure), and at least 6 inches in height.

Grain and some other commodities are sold by stricken measure, that is, the measure is to be stricken with a round stick or roller, straight and of the same diameter from end to end.

Glazing and stone-cutting are estimated by the square ft.

Painting, plastering, paving, ceiling and paper-hanging are estimated by the square yard.

In estimating the paintings of mouldings, cornices, &c., the measuring line is carried into all the mouldings and cornices.

Flooring, partitioning, roofing, slating and tiling are estimated by the square of 100 square feet.

A thousand shingles are estimated to cover 1 square, being laid 5 inches to the weather.

A span is the distance that can be reached between the end of the middle finger and the end of the thumb. Among sailors, 8 spans are equal to 1 thumb.

A geographic mile is $\frac{1}{21600}$ of the distance around the centre of the earth.

A square mile of land is called a section.

A Gunter's chain, used by land surveyors, is 4 rods or 66 feet long, and consists of 100 links. 7.92 inches make a link.

Canal and railroad engineers use an engineer's chain, which consists of 100 links, each 1 foot long.

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## TABLE OF COLORS.

*Used in Architectural and Mechanical Drawing.*

| Work. | Color. |
|---|---|
| Brickwork in plan or section.. | Carmine, or crimson lake. |
| " in elevation..... | Venetian red. |
| " to be removed by alterations, flintwork or lead | Prussian blue. |
| Concrete works, stone..... | Sepia. |
| Clay, earth..... | Burnt umber. |
| Granite ..... | Purple madder. |
| Timber (oak excepted)..... | Raw sienna. |
| Oak, teak..... | Burnt sienna. |
| Fir, and most other timber..... | Indian yellow. |
| Mahogany ..... | Indian red. |
| Cast iron, and wrought iron in the rough..... | Payne's grey. |
| Wrought iron, bright..... | Indigo. |
| Steel, bright..... | Indigo, with a little lake. |
| Brass ..... | Gamboge. |
| Gun metal..... | Dark cadmium. |
| Meadow land..... | Hooker's green. |
| Sky effects..... | Cobalt blue. |

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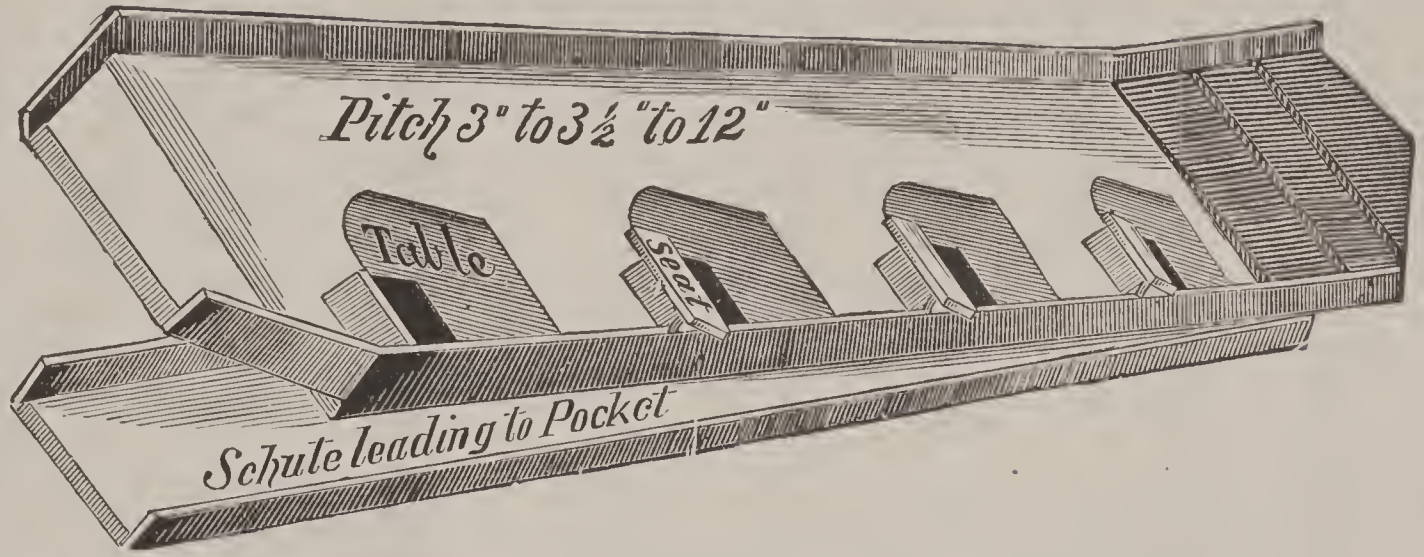


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FIG. 49 IN REFERENCE BOOK.

Question 327 in REFERENCE BOOK.—If you had an incline plane lying at angle of 1 in 5 or the vertical rise was 20 feet in every 100 in length, what power or equivalent weight would you require to balance a load of 500 lbs., reckoning friction at one eighty-second of the load. (See REFERENCE BOOK for a number of questions and figures on this subject.)

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